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# Selected Irrigation Return Flow Quality Abstracts, 1974
## Fourth Annual Issue

Colorado State Univ.

**Prepared For**
Robert S. Kerr Environmental Research Lab.

March 1976

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Research related to the quality of irrigation return flow is being conducted at numerous institutions throughout the western United States. Related work is also underway at other institutions in the United States, as well as other portions of the world. Approximately 100 sources of material have been searched for articles pertinent to the National Irrigation Return Flow Research and Development Program. These articles describe water quality problems resulting from irrigated agriculture, potential technological solutions for controlling return flows, recent research pertinent to return flow investigations, and literature associated with institutional constraints in irrigation return flow quality control. The first annual issue of SELECTED IRRIGATION RETURN FLOW QUALITY ABSTRACTS covered publications printed in 1968 and 1969, while the second annual issue lists publications printed in 1970 and 1971, and the third annual issue covers calendar years 1972 and 1973. This annual issue lists publications printed in 1974. This report was submitted in fulfillment of Grant Number R-800426 under the sponsorship of the Office of Research and Development, Environmental Protection Agency. (Skogerboe-Colorado State)

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# SELECTED IRRIGATION RETURN FLOW
# QUALITY ABSTRACTS, 1974

Fourth Annual Issue

by

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# FOREWORD

The fourth annual issue of SELECTED IRRIGATION RETURN FLOW QUALITY ABSTRACTS has been compiled from approximately 100 sources of material covering calendar year 1974. This compilation has attempted to include technological and institutional articles that would be pertinent to action programs regarding the control of water quality degradation resulting from irrigated agriculture.

The state-of-the-art report, "Characteristics and Pollution Problems of Irrigation Return Flow" prepared by the Utah State University Foundation contains a bibliography of articles pertinent to Irrigation Return Flow Quality through 1967. The first annual issue of SELECTED IRRIGATION RETURN FLOW QUALITY ABSTRACTS listed publications appearing in calendar years 1968 and 1969, while the second annual issue listed publications appearing in calendar years 1970 and 1971, and the third annual issue contained abstracts of articles and reports published during calendar years 1972 and 1973. The fourth annual issue contains 422 abstracts of documents published during calendar year 1974. The abstracts have been placed into sections according to the category and subgroup classifications used by the Water Resources Scientific Information Center (WRSIC) as published in the report, "Water Resources Thesaurus." The abstracts have been forwarded to WRSIC for inclusion in their bi-monthly publication, "Selected Water Resources Abstracts."

# ABSTRACT

Research related to the quality of irrigation return flow is being conducted at numerous institutions throughout the western United States. Related work is also underway at other institutions in the United States, as well as other portions of the world. Approximately 100 sources of material have been searched for articles pertinent to the National Irrigation Return Flow Research and Development Program. These articles describe water quality problems resulting from irrigated agriculture, potential technological solutions for controlling return flows, recent research pertinent to return flow investigations, and literature associated with institutional constraints in irrigation return flow quality control.

The first annual issue of SELECTED IRRIGATION RETURN FLOW QUALITY ABSTRACTS covered publications printed in 1968 and 1969, while the second annual issue lists publications printed in 1970 and 1971, and the third annual issue covers calendar years 1972 and 1973. This annual issue lists publications printed in 1974. This report was submitted in fulfillment of Grant Number R-800426 under the sponsorship of the Office of Research and Development, Environmental Protection Agency.

Key Words: Fertilizers, Irrigated Land, Irrigation Systems, Irrigation Water, Nitrates, Phosphates, Return Flow, Salinity, Water Pollution Effects, Water Pollution Sources, Water Quality Control.

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The efforts of Ms. Betty Doss, Ms. Lee Kettering, Ms. Teresa Skogg, and Ms. Sandra Geohring in preparing the necessary forms which are forwarded to the Water Resources Scientific Information Center are sincerely appreciated, as well as the typing of this final report. The organizational procedures, which have proven highly effective, are the result of previous efforts by Ms. Betsy Zakely.

The scope of this literature abstracting effort has been delineated jointly by the senior author and the Project Officer, Dr. James P. Law, Jr., Program Director, Agricultural Wastes Section, Treatment and Control Research, Robert S. Kerr Environmental Research Laboratory, Environmental Protection Agency, Ada, Oklahoma. The cooperative efforts of the Project Officer in meeting with project personnel and reviewing the abstracting process have been very helpful and are sincerely appreciated.

## Section I

# WATER CYCLE

## GENERAL (GROUP 02A)

74:02A-001
CALIBRATING A WATER YIELD MODEL FOR SMALL UNGAGED WATERSHEDS,
Jarboe, J.E. and Haan, C.T.
Kentucky Department of Natural Resources, Frankfort, Division of Water.
Water Resources Research, Vol. 10, No. 2, p 256-262, April 1974. 1 fig,
10 tab, 8 ref.

Descriptors: *Water yield, *Mathematical models, *Kentucky, Systems analysis, Rainfall-runoff relationships, Optimization, *Small watersheds.

A four-parameter water yield model was calibrated on 17 Kentucky watersheds by relating the model parameters to watershed topographic, geologic, and soil characteristics. The relationships were tested by comparing observed and simulated runoff records from six watersheds that were not contained in the original 17 watersheds. The results show that the water yield model can be satisfactorily applied to ungaged basins.

74:02A-002
STREAMFLOW SIMULATION: 3. THE BROKEN LINE PROCESS AND OPERATIONAL HYDROLOGY,
Mejia, J.M., Dawdy, D.R. and Nordin, C.F.
Ecole Polytechnique, Montreal (Quebec). Hydraulic Division.
Water Resources Research, Vol. 10, No. 2, p 242-245, April 1974. 11 ref.

Descriptors: *Synthetic hydrology, *Simulation analysis, *Statistical models, Markov processes, Stochastic processes, Regression analysis, Probability, Variability.

Broken line processes can be used to produce a standardized Gaussian process. An extension of the theory of the broken line process leading to the generation of processes preserving the mean, the variance, and a skewness coefficient different from zero is presented. The broken line process allows the modeling of cross-correlated sequences, for which it is possible to reproduce the value of H, the second spectral moment for a continuous process or the first serial correlation coefficient for a discrete one, and the first three moments for each of the sequences as well as the lag zero cross correlation among them. In addition, by proper structuring of the broken line process, parameter estimates may be preserved by simple algorithms. The addition of simple broken line processes is a useful operational tool for the synthesis of skewed multivariate sequences exhibiting the Hurst phenomenon. It can be used for continuous as well as discrete processes.

74:02A-003
MODELING OF STOCHASTIC-DETERMINISTIC HYDROLOGIC SYSTEMS,
Laurenson, E.M.
Monash University, Clayton, Australia, Department of Civil Engineering.
Water Resources Research, Vol. 10, No. 5, p 955-961, October 1974. 5 fig, 6 tab,
3 ref.

Descriptors: *Hydrologic systems, *Stochastic processes, *Hydrologic models, *Flood frequency, *Unit hydrographs, Storage, Tides, Analytical techniques, Streamflow, Flood peak, Model studies.

Most hydrologic systems have both stochastic and deterministic components. The stochastic components are parameters defined by means of probability distributions, whereas the deterministic components are processes that can be modeled mathematically or graphically without probabilistic statements. Combined modeling of the stochastic and deterministic aspects of systems can lead to advances in many areas of hydrologic practice. Such modeling is achieved by matrix multiplication of a probability distribution of the stochastic system input with a transitional matrix derived from the deterministic operation of the system and any stochastic parameter. This method was demonstrated for a wide range of applications. The method does not help to define the deterministic relations among variables nor the probability distributions of variables. It does provide a convenient means of mixing the deterministic and the stochastic aspects of systems.

74:02A-004
CHANGES IN ARTIFICIAL DRAINAGE, FERTILIZERS, AND CLIMATE IN SCOTLAND,
Green, F.H.W.
Oxford University, Parks Road, Department of Agricultural Science.
Journal of Environmental Management, Vol. 2, No. 2, p 107-121, April 1974.
10 fig, 2 tab, 6 ref.

Descriptors: *Environmental effects, Drainage effects, Drainage systems, Fertilization, Fertilizers, Climatic data, Climates.

A recently published paper (Green, 1973) drew attention to certain environmental changes, some natural and some man-made, which have been taking place concurrently in recent years, and which are affecting both water in streams, and the water level in the soil. Because the available data, on either side of the Border, were not strictly comparable, the former paper had to be restricted to England and Wales. The present paper deals with Scotland in a generally similar manner. The environmental changes considered are field drainage, use of fertilizers, and climatic changes.

# Section II

# WATER CYCLE

## SNOW, ICE, AND FROST (Group 02C)

74:02C-001
### EFFECTS OF SALT CONCENTRATION CHANGES DURING FREEZING ON THE UNFROZEN WATER CONTENT OF POROUS MATERIALS,
Banin, A. and Anderson, D.M.
Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire.
Water Resources Research, Vol. 10, No. 1, p 124-128, February 1974. 4 fig, 2 tab, 12 ref.

Descriptors: *Freezing, *Saline water, *Porous media, *Frozen soils, Frozen ground, Permafrost, Frost, Soil water, Aqueous solutions, Equations, Salts.

By combining equations for salt concentration by water removal from porous bodies with those for freezing point depression in normal solutions, equations were developed for calculating freezing point depression shifts due to the gradual removal of water upon freezing in porous bodies. The same equations can be used for the calculation of shifts in the osmotic potential of the water in drying porous bodies by using a simple conversion factor. Graphs relate the remaining water content to the freezing point shift for various initial soluble salt contents. Good agreement was found between the measured freezing point depression in a silty clay soil treated with three concentrations of sodium chloride and with dimethyl sulfoxide at various contents of unfrozen water and the calculated values.

74:02C-002
### WATER FLOW THROUGH SNOW OVERLYING AN IMPERMEABLE BOUNDARY,
Colbeck, S.C.
Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire.
Water Resources Research, Vol. 10, No. 1, p 119-123, February 1974. 3 fig, 14 ref.

Descriptors: *Snowpacks, *Melt water, *Percolation, *Unsaturated flow, Infiltration, Water yield, Temperature, Snowmelt, Glaciohydrology, Melting, Mathematical models.

A two-layer model describes water flow over an impermeable boundary. The model consists of vertical flow through an unsaturated layer and flow along a boundary in a saturated layer. The governing equations are solved for the nonsteady case, where the gradient of the thickness of the saturated layer is small compared with the slope of the impermeable boundary. In most cases the discharge from shallow snowpacks will preserve the diurnal cycles of input at the surface, although for deep snowpacks (such as temperate glacier firn) the diurnal cycle is smoothed and only long-term responses are expected. The flow of a diurnal meltwater wave through a small (2.10 m deep by 100 m long) snowpack was calculated as an example. The case of steady flow is also described.

## Section III

## WATER CYCLE

### EVAPORATION AND TRANSPIRATION (Group 02D)

74:02D-001
A SENSITIVITY AND ERROR ANALYSIS OF PROCEDURES USED FOR ESTIMATING EVAPORATION,
McCuen, R.H.
Maryland University, College Park, Department of Civil Engineering.
Water Resources Bulletin, Vol. 10, No. 3, p 486-497, June 1974. 3 tab, 11 ref.

Descriptors: *Evaporation, Mathematical studies, Equations, Meteorology, Variability, Heat transfer, Heat budget, Winds, Model studies.

The structure of commonly used evaporation models, the effect of variation in meteorological factors on observed evaporation rates, and the effect of error in measurements of the meteorological factors were studied by sensitivity and error analyses. Error in evaporation estimates resulting from measurement error in meteorological factors in probably much less than 5% of the computed evaporation rate. The importance of the different meteorological factors varies in time and space. The sensitivity analysis indicates that the Fractional-Evaporation Equivalent method is structurally inadequate and the Weather Bureau model is more flexible than the Penman model. However, the Penman model provides more realistic estimates of the importance of the various meteorological factors.

74:02D-002
PREDICTION OF WATER LOSS FROM A FALLOW FIELD SOIL BASED ON SOIL WATER FLOW THEORY,
Gardner, H.R.
Agricultural Research Service, Fort Collins, Colorado.
Soil Science Society of America Proceedings, Vol. 38, No. 3, p 379-382, May-June 1974. 6 fig, 1 tab, 4 ref.

Descriptors: *Evaporation, *Water loss, *Soil water movement, Equations, Evapotranspiration, Diffusivity, Soil moisture, Water balance.

Evaporation from nonhomogeneous field soils may be predicted by a simple technique based on soil water flow theory. From cumulative evaporation measurements on undisturbed cores of soil, a dimensionless curve is drawn relating fractional water loss to the square root of time divided by the amount of water available for evaporation. A procedure is described to account for the residual water left in the soil from one rainfall event to the next. Predictions of cumulative evaporation made by the use of the dimensionless curve were compared with 4 years of lysimeter data on Rago silt loam. The system should work best in an area with high average potential evaporation and low rainfall such as the Great Plains.

74:02D-003
ESTIMATING EVAPOTRANSPIRATION USING CANOPY TEMPERATURES: FIELD EVALUATION,
Stone, L.R. and Horton, M.L.
Kansas Agricultural Experiment Station, Manhattan, Evapotranspiration Laboratory.
Agronomy Journal, Vol. 66, No. 3, p 450-454, 1974, Illus.

Thermal scanners provide a possible way of estimating water loss from surface by using remotely sensed surface temperatures. In this study, designed to evaluate the feasibility of using canopy temperatures in estimating evapotranspiration(ET), 5 equations were used. Sorghum bicolor L. (Moench) was used in the field investigation. Three of the equations were the well-known methods of van Bavel, Penman and energy budget-Bowen ratio. The other 2 use the temperature of the evaporating surface in estimating ET and are referred to as the Bartholic-Namken-Wiegand (B-N-W) and Brown-Rosenberg (B-R) methods. Using simple linear regression and correlation analyses, the B-N-W estimates were found to be approximately 17% smaller and the B-R estimates to be approximately 22% larger than typical estimates obtained by the Penman and energy budget-Bowen ratio methods. Both methods appear usable in determining ET rates of vegetated surfaces, with the B-N-W method requiring less input data than the B-R method.

74:02D-004
WATER CONSUMPTION OF IRRIGATED CROPS,
Balogh, J.
Research Institute of Water Resources Management, Budapest, Hungary.
International Commission on Irrigation and Drainage, p 18-24, July 1974. 2 fig, 16 ref.

Descriptors: *Evapotranspiration, *Lysimeters, Irrigation, Moisture tension, Consumptive use, Soil-plant-water relationships, Instrumentation, Irrigation practices.

The author, in analyzing the variation in irrigation water requirement and irrigation water need, interprets the potential, maximal and actual values of evapotranspiration. For this purpose, he analyses the complex ensembles of the vapour absorption and vapourizing systems of the soil-plant-atmosphere and vegetation space. He then examines the most important methods and instruments for the evapotranspiration and the types of the obtainable values of evapotranspiration. It has been established that the values of water consumption of irrigated crops only diverge little from the values of its evapotranspiration, and the evapotranspiration of irrigated crops is necessarily less than the potential or maximal values of evapotranspiration, but it is always higher than the actual evapotranspiration without irrigation.

## Section IV

## WATER CYCLE

### STREAMFLOW AND RUNOFF (Group 02E)

74:02E-001
SURFACE WATER NETWORK DESIGN BY REGRESSION ANALYSIS SIMULATION,
Moss, M.E. and Karlinger, M.R.
Geological Survey, Reston, Virginia, Water Resources Division.
Water Resources Research, Vol. 10, No. 3, p 427-433, June 1974. 7 fig, 1 tab, 5 ref.

Descriptors: *Streamflow forecasting, *Regression analysis, *Simulation analysis, Network design, *Water transfer, Water supply, Statistical models, Interbasin transfers, Water resources development, Planning, Water management(Applied).

Statistical characteristics of the accuracy of regression analyses as used in surface water regionalization were investigated by simulating logarithmic regressions of the streamflow parameters, mean and standard deviation, derived from synthetic streamflow sequences. Accuracy was measured in terms of equivalent years of at-site record. A procedure for design of surface water data networks that accounts for the statistical nature of estimates of parameter accuracy is presented.

74:02E-002
TWO-DISTRIBUTION METHOD FOR MODELING AND SEQUENTIAL GENERATION OF MONTHLY STREAMFLOWS,
Singh, K.P. and Lonnquist, C.G.
Illinois State Water Survey, Urbana, Hydrology Section.
Water Resources Research, Vol. 10, No. 4, p 763-773, August 1974. 6 fig, 2 tab, 21 ref.

Descriptors: *Synthetic hydrology, *Time series analysis, *Model studies, *Distribution patterns, Statistical methods, Streamflow, Hydrologic data, Analytical techniques, Correlation analysis, Probability, Computer programs, *Illinois.

Distributions of observed monthly streamflows at many gaging stations exhibit slight, moderate, or sharp reverse curvatures that cannot be accommodated by the commonly used classical distributions such as the normal and gamma (Pearson type 3) distributions applied to flows or their logarithms. The two distribution, essentially a bimodal distribution, fits most of these observed distributions very well. A unique and versatile method for modeling and sequential generation of monthly streamflows was presented. In order to assure the normality of the multivariate distribution of variables representing monthly flows, the flows or their logarithms were converted to standardized normal deviates by suitable transforms. The distributions of monthly streamflows generated by the two-distribution method fit best the observed flow distributions. Annual flows obtained by summing generated monthly flows fit the observed annual flows very well. The use of the two-distribution method can obviate arbitrary adjustments in generated monthly flows to bring the annual flows obtained from them in line with observed annual flows.

74:02E-003
HYDROCHEMISTRY OF THE ATHABASCA AND NORTH SASKATCHEWAN RIVERS IN THE ROCKY MOUNTAINS OF CANADA,
Drake, J.J. and Ford, D.C.
McGill University, Montreal, Quebec, Canada, Department of Geography.
Water Resources Research, Vol. 10, No. 6, p 1192-1198, December 1974. 4 fig, 3 tab, 12 ref.

Descriptors: *River flow, River forecasting, River systems, Model studies, Rivers, Canada, Theoretical analysis.

The hydrochemical behavior of the Athbasca and North Saskatchewan rivers at their points of departure from the Rocky Mountains during the period May 1967 to February 1970 is shown to be well represented by a model based upon the mixing of two water bodies. These component sources contribute varying proportions of the total discharge through the year. One of them has properties that are in keeping with the theoretically expected and the observed characteristics of surface runoff water in the area and essentially represents snowmelt water. The properties of the other component are similarly in keeping with those expected and observed for groundwater in the rock and glacial aquifers of the area.

74:02E-004
PROCEDURES FOR DETERMINING THE ORDER OF DEPENDENCE IN STREAMFLOW RECORDS,
Denny, J.L., Kisiel, C.C. and Yakowitz, S.J.
Arizona University, Tucson, Department of Mathematics.
Water Resources Research, Vol. 10, No. 5, p 947-954, October, 1974. 2 tab, 17 ref.

Descriptors: *Streamflow, Streamflow forecasting, Streams, Markov processes, Hydrology, Model studies, Statistical methods, Statistics.

As will be documented in detail, a common feature of all the streamflow models in the literature is that they assume some known order of Markov dependency to be available prior to calibration of the model parameters. Yet the statistical methods for finding this order are subtle and perhaps may themselves need refinement. In brief, the problem of finding the minimum order of Markov dependence is a difficult one and yet one that must be faced no matter what streamflow model is selected. This study is devoted in the main to setting forth the extant statistical techniques available for this problem of determining Markov order and applying the stated techniques to finding the order of records of particular rivers in the Tucson basin. Care is taken in describing the hydrologic properties of the rivers studied, since these properties may ultimately be crucial in establishing some a priori feelings for the range of likely orders.

# Section V

## WATER CYCLE

### GROUNDWATER (Group 02F)

74:02F-001
WATER-TABLE FLUCTUATION IN RESPONSE TO RECHARGE,
Marino, M.A.
California University, Davis, Department of Water Science and Engineering.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 100, No. IR2, Paper 10582, p 117-125, June 1974. 2 fig, 10 ref, append.

Descriptors: *Recharge, *Water level fluctuations, *Water spreading, Groundwater, Equations, Irrigation, Water table, Surface-groundwater relationships.

Analytical expressions were developed to describe the rise and fall of the water table in an extensive unconfined aquifer receiving localized vertical recharge and discharging into a surface reservoir in which the water level remains equal to that of the main flow before recharge. The rate of recharge is maintained by a spreading area in the form of an infinitely long strip of finite width. The solutions are expressed in terms of the head averaged over the depth of saturation. They are applicable when the rise of the water table is smaller than 50% of the initial depth of saturation. A numerical example is presented.

74:02F-002
A DATA ACQUISITION SYSTEM FOR TRANSIENT POROUS MEDIA EXPERIMENTS IN A SECTOR TANK,
Orhun, A. and Luthin, J.N.
California University, Davis, Department of Water Science and Engineering.
Water Resources Research, Vol. 10, No. 3, p 601-604, June 1974. 6 fig, 1 ref.

Descriptors: *Unsteady flow, *Groundwater movement, Data collections, Permeameters, Porous media, Hydraulic models, Piezometers, Data processing.

A simple, fast, and reliable data acquisition system was designed to study groundwater flow problems under transient conditions. The data needed include soil water pressure at various locations and the outflow from the well. A sector tank was constructed for the experimental verification of the computer solutions. The grid of pressure tap points was chosen in such a way that interpolations for the equipotentials deviating from vertical lines could easily be made along the diagonals of the network. All the pressure measurements were made by piezometers constructed from 1/4-inch stainless steel tubings.

74:02F-003
STOCHASTIC ANALYSIS OF PHREATIC AQUIFERS,
Gelhar, L.W.
Massachusetts Institute of Technology, Cambridge, Department of Civil Engineering.
Water Resources Research, Vol. 10, No. 3, p 539-545, June 1974. 6 fig, 19 ref.

Descriptors: *Surface-groundwater relationships, *Statistical models, *Stochastic processes, Alluvial channels, Recharge, Discharge(Water), Water table, Water level fluctuations.

Three analytical models were developed to describe the spectral response characteristics of phreatic aquifers subject to time variable accretion and fluctuations in adjacent stream stage. A linear reservoir model approximates the behavior of a more complete distributed linear model based on the Dupuit approximation if a single parameter is adjusted appropriately. A linearized two-dimensional analysis including the effects of vertical flow shows, under conditions of large anisotrophy with relatively narrow partially penetrating streams, differences from the Dupuit analysis that may be important under some field conditions. Possible applications of the results in aquifer evaluation are suggested.

74:02F-004
SENSITIVITY ANALYSIS OF INPUT PARAMETERS IN NUMERICAL MODELING OF STEADY STATE REGIONAL GROUNDWATER FLOW,
Gillham, R.W. and Farvolden, R.N.
Geulph University, Ontario, Department of Land Resource Science.
Water Resources Research, Vol. 10, No. 3, p 529-538, June 1974. 9 fig, 15 ref.

Descriptors: *Numerical analysis, *Groundwater movement, *Groundwater basins, Mathematical models, Finite element analysis, Hydraulic conductivity.

To study regional groundwater flow, a finite element model was used to examine the sensitivity of computed hydraulic head values to changes in the hydraulic conductivity. Steady state saturated flow in non-uniform anisotropic cross sections was considered. The sensitivity analysis procedure was useful in locating those areas of the flow system most sensitive to changes in conductivity and in determining those components of conductivity that have the greatest effect on the hydraulic head distribution. Consequently, a sensitivity analysis is very useful in designing efficient hydraulic conductivity measurement programs. One method that has frequently been used to determine conductivities is to adjust the conductivity components in a numerical model until the computed head value agree with field measurements; this procedure could lead to erroneous conclusions. By using sensitivity analyses, a method was developed for determining the quantitative value of ratios of conductivity components from field measurements of hydraulic head. In principle, the number of head measurements must be equal to the number of unknown conductivity ratios.

74:02F-005
NONLINEAR TECHNOLOGICAL FUNCTIONS FOR AQUIFERS WHOSE TRANSMISSIVITIES VARY WITH DRAWDOWN,
Maddock, T., III.
Geological Survey, Reston, Virginia.
Water Resources Research, Vol. 10, No. 4, p 877-881, August 1974. 1 fig, 7 ref.

Descriptors: *Drawdown, *Transmissivity, *Aquifers, *Water level fluctuations, *Unsteady flow, Aquifer testing, Water table, Mathematical studies, Equations.

An algebraic technological function (AFT) exists for an aquifer whose flow to wells can be remodeled by Boussinesq's equation. Drawdown is an infinite power series in pumping values, and the ATF is provided by a finite sum of the power series. The number of terms necessary for the finite sum to provide a good approximation to the infinite series depends on a ratio of drawdown to saturated thickness. The ATF can be used in optimization techniques or as a method for predicting drawdowns from pumping.

74:02F-006
TRACING SHALLOW GROUNDWATER SYSTEMS BY SOIL TEMPERATURES,

Cartright, K.
Illinois State Geological Survey, Urbana.
Water Resources Research, Vol. 10, No. 4, p 847-855, August 1974. 9 fig, 23 ref.

Descriptors: *Illinois, *Groundwater movement, *Soil temperature, *Heat flow, Discharge(Water), Recharge, Aquifer characteristics, Glacial aquifers, Flow system.

Circulating water is known to affect the temperature of the rock through which it flows. Analysis of existing theoretical equations suggests that shallow groundwater flow will also affect the surface soil temperature. Soil temperatures therefore might be used to delineate small, shallow groundwater flow systems; both recharge and discharge zones might be distinguished. Temperature data taken in the field during summer and winter support these theoretical conclusions and agree with the groundwater flow patterns inferred from hydrologic data. In general, winter soil temperature profiles have less data scatter than profiles of summer temperatures. The greater the rate of groundwater flow, the greater the temperature difference between recharge and discharge zones. Temperature variations ranged from 0.75C in clayey glacial till to 5C in sand. The effect on soil temperature also decreases with increasing horizontal distance between the recharge and the discharge zone. The effect of horizontal flow in a shallow confined aquifer is also predictable from theoretical models and can be shown by field studies. The amount of heat redistributed depends on the thermal properties of the aquifer and on overburden and the velocity of fluid flow.

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74:02F-007
IDENTIFICATION OF PARAMETERS IN AN INHOMOGENEOUS AQUIFER BY USE OF THE MAXIMUM PRINCIPLE OF OPTIMAL CONTROL AND QUASI-LINEARIZATION,
Lin, A.C. and Yeh, W. W-G.
California University, Los Angeles, Department of Systems Engineering.
Water Resources Research, Vol. 10, No. 4, p 829-838, August 1974. 3 fig, 3 tab, 13 ref, 1 append.

Descriptors: *Aquifer characteristics, Diffusivity, Optimization, Linear programming, *Least squares method, Mathematical studies, Parametric hydrology, Mathematics, Observation wells, Wells, Groundwater, Computer models, Aquifers.

Optimal identification of aquifer parameters in a distributed system was formulated as an optimal control problem. The dynamics of the head was governed by a second-order nonlinear partial differential equation. The numerical example presented considers that the parameters to be identified were functions of the space variable. Observations on head variations were available at several observation wells distributed within the system. Spatial discretization was first used to transform the distributed system to a lumped system. The least squares criterion function was then established. After introducing the Lagrange multipliers, the maximum principle was applied to obtain the set of necessary conditions that is optimal. These conditions were expressed in terms of a set of canonic equations of two-point boundary value type that is easily solved by the technique of quasi-linearization. Thus aquifer parameters were directly identified on the basis of observational data taken at observation stations. The maximum principle formulation is inherently more accurate and stable, since it minimizes the least squares error over the whole time and space domains. Computationally, it is extremely efficient. The numerical example presented demonstrates simultaneous identification of 11 parameters defined at discretized points along the space variable. Quadratic convergence was also demonstrated by numerical experimentation.

74:02F-008
GALERKIN APPROXIMATION OF THE TIME DERIVATIVE IN THE FINITE ELEMENT ANALYSIS OF GROUNDWATER FLOW,
Gray, W.G. and Pinder, G.F.
Princeton University, New Jersey, Department of Civil and Geological Engineering.
Water Resources Research, Vol. 10, No. 4, p 821-828, August 1974. 6 fig, 2 tab, 12 ref.

Descriptors: *Finite element analysis, *Groundwater movement, Mathematical models, Simulation analysis, Numerical analysis, Time series analysis.

The Galerkin method of approximation permits a high-order approximation in time as well as in space in finite element analysis of groundwater movement. The resulting approximate equations may successfully be solved by using a prismatic element with triangular cross section. The time axis runs the length of the prism and is subdivided into elements that may be linear, quadratic, or cubic. Because this formulation requires in general the solution for several time levels simultaneously, there is a resulting increase in computer time required to solve the larger matrix. Numerical experiments indicate that the selection of an optimum numerical scheme is dependent not only on the particular problem considered but also on the sequence of time steps used.

74:02F-009
INTEGRODIFFERENTIAL EQUATIONS FOR SYSTEMS OF LEAKY AQUIFERS AND APPLICATIONS 2. ERROR ANALYSIS OF APPROXIMATE THEORIES,
Herrera, I.
Universidad Nacional Autonoma deMexico, Mexico City, Centro de Investigacion en Matematicas Aplicadas y Sistemas.
Water Resources Research, Vol. 10, No. 4, p 811-820, August 1974. 2 fig, 1 tab, 17 ref, 1 append.

Descriptors: *Aquitards, Drawdown, Storage capacity, Permeability.

This paper is the second of a series devoted to developing a method of analysis based on the integrodifferential equations of leaky aquifer systems. In part 1 (Herrera and Rodarte, 1973a) (W73-13378) the integrodifferential equations were derived, and an interpretation for some of the approximate theories was given in terms of the memory functions occurring in the equations. The same equations are quite suitable for a systematic analysis of the errors involved, and therefore in this paper they are used to carry it out.

74:02F-010
DRAWDOWN DISTRIBUTION DUE TO WELL FIELDS IN COUPLED LEAKY AQUIFERS, 1. INFINITE AQUIFER SYSTEM,
Saleem, Z.A. and Jacob, C.E.
Illinois University, Chicago, Department of Geological Sciences.
Water Resources Research, Vol. 9, No. 6, p 1671-1678, December 1973. 1 fig, 14 ref.

Descriptors: *Drawdown, *Artesian aquifers, *Aquifer systems, Leakage, Mathematical studies, Equations, Aquifer characteristics, Confined water.

Solutions for drawdown distribution caused by the pumping of well fields in single aquifers were obtained for a limited number of cases. However, most of the aquifers in nature are not single isolated aquifers. Consequently, the use of presently available solutions can yield unreasonable results. Equations for the drawdown distribution caused by the pumping of well fields in two coupled leaky aquifers are presented. Two cases of the system are analyzed. Case 1 is the upper aquifer when it is confined or unconfined and the drawdown in it is very small in comparison with its saturated thickness; in case 2 the drawdown in the upper unconfined aquifer can be significant. Approximate solutions for relatively short and long times, as well as solutions for special cases, are presented. The solutions involve integrals that can be evaluated by using a digital computer.

74:02F-011

EFFECT OF PARTIAL PENETRATION ON FLOW IN UNCONFINED AQUIFERS CONSIDERING DELAYED GRAVITY RESPONSE,

Neuman, S.P.

Agricultural Research Organization, Bet-Dagan, Israel, Institute of Soils and Water.

Water Resources Research, Vol. 10, No. 2, p 303-312, April 1974. 7 fig, 28 ref.

Descriptors: *Groundwater movement, *Unsaturated flow, Water table, Water level fluctuations, Pumping, Water yield, *Storage coefficient, Specific yield, Simulation analysis.

The delayed response process characterizing flow to a well in an unconfined aquifer can be simulated by using constant values of specific storage and specific yield without recourse to unsaturated flow theory. The theory is extended to account for the effect of a well partially penetrating a homogeneous anisotropic unconfined aquifer. Field and laboratory evidence suggests that the elastic storage properties of unconfined aquifers may often be much more pronounced than those of deep-seated confined aquifers composed of similar materials.

74:02F-012

MATHEMATICAL SIMULATION OF SUBSURFACE FLOW CONTRIBUTIONS TO SNOWMELT RUNOFF, REYNOLDS CREEK WATERSHED, IDAHO,

Stephenson, G.R. and Freeze, R.A.

Agricultural Research Service, Boise, Idaho, Northwest Watershed Research Center.

Water Resources Research, Vol. 10, No. 2, p 284-294, April 1974. 10 fig, 2 tab, 14 ref.

Descriptors: *Simulation analysis, *Subsurface runoff, *Snowmelt, Groundwater movement, Soil water movement, Base flow, Snowpacks, Mathematical models, *Idaho, Infiltration.

A mathematical model of subsurface flow complements a field study of snowmelt runoff in a small upstream source area in the Reynolds Creek Experimental Watershed near Boise, Idaho. Field measurements from an instrumented cross section of this small watershed show that the mechanism of streamflow generation is subsurface delivery of meltwater over limited distances through shallow high-permeability low-porosity formations of altered and fractured basalt. The mathematical model provides a two-dimensional transient saturated-unsaturated analysis of the subsurface flow at the field site. It was a valuable aid to a unified interpretation of the field measurements. For mathematical models that consist of boundary value problems with boundary conditions that are time and space dependent, the boundary condition sensitivity can thwart the rational calibration-validation procedure. This, together with the more serious limitations of data availability, funds for data acquisition, and computer capacity, precludes the imminent use of fully deterministic hydrologic response models on larger basins or on a regional scale.

74:02F-013

**ANALYSIS OF UNSTEADY FLOW TOWARD ARTESIAN WELLS BY THREE-DIMENSIONAL FINITE ELEMENTS,**

Huang, Y.H. and Wu, S-J.
Kentucky Water Resources Research Institute, Lexington.
Water Resources Research, Vol. 10, No. 3, p 591-596, June 1974. 4 fig, 9 ref.

Descriptors: Anisotrophy, *Artesian wells, *Computer programs, *Computer models, Aquifers, Digital computers, Drawdown, *Finite element analysis, Groundwater, Heterogeneity, Numerical analysis, *Unsteady flow.

A three-dimensional finite element computer program was developed for analyzing unsteady flow toward artesian wells. The program is designed especially for determining the drawdown around an artesian well penetrating fully or partially a nonhomogeneous and anisotropic aquifer and irregular shape and cross section. It can also be used as a general program for aquifer simulation and evaluation. A major advantage of the program lies in the minimum amount of input data required. By assuming the top and bottom boundaries of the aquifer as two arbitrary planes, the aquifer will be divided into six- or eight-node elements, and their nodal coordinates generated automatically. The program was well documented and can be used for solving complex problems encountered in practice. Results indicate that unsteady flow toward artesian wells can be analyzed effectively by three-dimensional finite elements. A comparison between the finite element and the exact mathematical solutions for a simple case shows that both solutions check closely. The solution obtained from the computer program for a complex case involving a nonhomogeneous aquifer was checked against that obtained previously by the use of cylindrical elements, and both are found in good agreement. The program was applied to a variety of cases, and reasonable results were obtained.

74:02F-014

**MATHEMATICAL MODELING OF WATER QUALITY FOR WATER RESOURCES MANAGEMENT, VOLUME II: DEVELOPMENT OF HISTORIC DATA FOR THE VERIFICATION OF THE GROUND WATER QUALITY MODEL OF THE SANTA CLARA-CALLEGUAS AREA, VENTURA COUNTY,**

Hassan, A.A., Kleinecke, D.C., Johanson, S.J. and Pierchala, C.E.
California State Department of Water Resources, Sacramento.
Available from the National Technical Information Service, Springfield, Virginia as PB-237 372. District Report, August 1974. 119 p, 35 fig, 25 tab, 25 ref.

Descriptors: *California, *Dissolved solids, *Groundwater movement, *Water quality, Model studies, Aquifers, *Mathematical models, Management, Data collections, *Saline water intrusion, *Chlorides, Percolation, Water levels.

Based on the evaluation of total dissolved solids in wells of different depths, vertical variation of quality was found to be insignificant in the Santa Clara-Calleguas area, except in the Oxnard Plain area which has three separate aquifer systems. In the Oxnard Plain area, the shallow perched aquifer was not modeled in either the quantity or quality model. Leakage from the perched aquifer served as an input to the upper layer nodes of the model. The Oxnard-Mugu aquifer system and the Hueneme, Fox Canyon, and Grimes Canyon system were modeled as separate layers of specific water quality values. The following are the main conclusions of the sea water intrusion study: (1) Based on the fluctuations of ground water levels and chloride concentrations in well water, it was possible to construct cross sections showing the sequential advance inland of the sea water front into the Oxnard aquifer. (2) Generally, chloride concentrations increased as water levels declined. (3) Sufficient data were available in the Port Hueneme area to relate the inland advance of sea water into the Oxnard aquifer to the decline in water levels. Data were insufficient to develop the same relationship in the Point Mugu area. (4) Increase in the chloride concentration of groundwater in the Point Mugu area may be due to sea water intrusion and also to percolation of saline water from the ground surface.

74:02F-015
MATHEMATICAL MODELING OF WATER QUALITY FOR WATER RESOURCES MANAGEMENT, VOLUME I: DEVELOPMENT OF THE GROUNDWATER QUALITY MODEL,
Hassan, A.A., Kleinecke, D.C., Johanson, S.J. and Pierchala, C.E.
California State Department of Water Resources, Sacramento.
Available from the National Technical Information Service, Springfield, Virginia as PB-237 371. District Report, August 1974. 191 p, 34 fig, 17 tab, 30 ref, 4 append.

Descriptors: *Dissolved solids, *Groundwater movement, Aquifers, *Groundwater basins, Dispersion, *Salts, *California, *Computer programs, Mixing, *Model studies, Computer models, *Saline water intrusion, Water utilization, Mathematical models, Water quality, Management.

A digital computer program was developed to estimate the concentration of total dissolved solids of extracted water from a multiaquifer groundwater basin. The model considered salt input from natural sources and from man's uses of water: domestic, industrial, and agricultural. The computer system was tested in the Santa Clara-Calleguas area in Ventura County, California.

74:02F-016
WATER AND SALT TRANSFERS IN SUTTER BASIN, CALIFORNIA,
Tanji, K.K., Henderson, D.W., Sumant, G., Iqbal, M. and Queck, A.F.
California University, Davis, Department of Water Science and Engineering
Presented at 1974 Annual Meeting of the American Society of Agricultural Engineers, June 23-26, 1974. Stillwater, Oklahoma. 8 fig, 3 tab, 10 ref.

Descriptors: *Saline water intrusion, Salinity, Saline water, California, Hydrogeology.

An analysis for water and salt transfers was carried in Sutter Basin, California. The average drainage index for the hydrologic years 1964-72 was estimated to be 0.42 ± 0.08 and the average salt balance index for the hydrologic years 1970-72 as 2.59 ± 1.25. For the 1970 hydrologic year the flow-weighted average surface input of salts (precipitation + irrigation water) was 0.1 tons per ac-ft and the surface output (return flow) 0.7 tons per ac-ft. About 40% of the water and 70% of the salt load in the return flow is estimated to have originated from subsurface origins, mainly rising connate water. Hydrogeologic evidence indicates that connate water is rising upwards under artesian pressure from about 2,500 to 3,000 ft below sea level. There is apparently no net deep percolation of water and the net flux of water and salts is from the subsurface to the land surface. This analysis shows that surface input-output relations do not give an adequate assessment of water quantity-water quality in Sutter Basin. When point source waste discharge permits are to be enforced in the future, they should consider natural geochemical sources like rising connate water in Sutter Basin.

74:02F-017
SIMULATION OF MISCIBLE DISPLACEMENT IN SOILS,
Smajstrla, A.G., Reddell, D.L. and Hiler, E.A.
Texas A&M University, College Station, Department of Agricultural Engineering.
Presented at 1974 Annual Meeting of the American Society of Agricultural Engineers, June 23-26, 1974. Stillwater, Oklahoma. 9 fig, 27 ref, 1 append.

Descriptors: *Infiltration, *Soil water movement, Porous media, Computer programs, Simulation analysis, Model studies.

A simulation model was developed to simulate the miscible displacement of a conservative solute during one-dimensional vertical infiltration into a homogeneous, isotropic porous media. FORTRAN IV computer programs were written in a general form so that various initial and boundary conditions could be specified as input parameters. As a result of this research, the following conclusions were drawn: 1. Unsteady vertical infiltration, steady flow dispersion, and dispersion during unsteady vertical infiltration into unsaturated, homogeneous, and isotropic porous media were accurately described by the simulation model; 2. The shape of the solute distribution curve with depth is relatively insensitive to the magnitude of the dispersion coefficient for porous media to which the functional relationship used apply and for the range of pore water velocities commonly encountered during infiltration into sand and clay loam soils; 3. Dispersion coefficients are much larger and solute curve are very different for nonhomogeneous, anisotropic porous media than for homogeneous media. Data describing the nonhomogeneous nature of soils will be needed to adequately describe experimental field solute distribution curves.

74:02F-018
THE SHAPE OF THE INTERFACE IN STEADY FLOW IN A STRATIFIED AQUIFER,
Mualem, Y. and Bear, J.
Technion-Israel Institute of Technology, Haifa, Israel, Department of Civil Engineering.
Water Resources Research, Vol. 10, No. 6, p 1207-1215, December 1974. 12 fig, 1 tab, 8 ref.

Descriptors: *Saline water-freshwater interfaces, Saline water, Saline water intrusion, Freshwater, Aquifer systems, Aquifers, Aquifer characteristics, Groundwater.

The present work deals with the shape of the interface in a coastal aquifer in which a thin horizontal semipervious layer is present. Field observations and laboratory experiments have shown that under these conditions a discontinuity in the shape of the interface occurs such that a freshwater region exists under the semipervious layer while immediately above it, saline (or mixed) water is present in the aquifer. The paper presents an approximate solution for the shape of the interface below the semipervious layer and for the extent of the freshwater region above it under steady state conditions. The solution is based on the Dupuit assumption and on a linearization of part of the flow equations.

74:02F-019
HYDROGEOCHEMISTRY OF CARBONATE GROUNDWATERS OF AN URBAN AREA,
Long, D.T. and Saleem, Z.A.
Illinois University, Chicago, Department of Geological Sciences.
Water Resources Research, Vol. 10, No. 6, p 1229-1238, December 1974. 4 fig, 5 tab, 29 ref.

Descriptors: *Groundwater, *Water quality, *Carbonates, Aquifer, Ions, Model studies.

A comparison of the groundwater chemical data from the shallow dolomite aquifer of Northeastern Illinois Metropolitan Area (NIMA) from August 1972 through April 1973 with data collected 12-40 yr earlier indicates that concentrations of all ions have increased, the greatest increase occurring in the southeastern part of the area where the overburden is thinnest. The largest increases are 843, 142, and 91% in Cl(-), SO4(2-), and Na(+), respectively. However, the spatial distribution of the groundwater chemical types has remained the same with time. The groundwater was found to be apparently supersaturated with respect to calcite and dolomite; however, the two saturation indices were reduced by 20 and 30%, respectively, after considering the effect of ion pairings. The chemical character of the groundwater is controlled, among other factors, by the change of carbon dioxide content of the water along the groundwater flow path. A model for the solution of dolomite based on the standard equations for carbonate equilibrium is presented. The application of the model to the study area indicates that a variety of geologic conditions between the dolomite aquifer and the overlying glacial drift prevail in the area.

74:02F-020
THESIS EQUATION ANALYSIS OF RESIDUAL DRAWDOWN DATA,
Case, C.M., Pidcoe, W.W., and Fenske, P.R.
Nevada University, Reno, Center for Water Resources Research, Desert Research Institute.
Water Resources Research, Vol. 10, No. 6, p 1253-1256, December 1974. 1 fig, 2 tab, 11 ref.

Descriptors: *Aquifer characteristics, Aquifer testing, Aquifers, Theis equation, Transmissivity, Storage coefficient.

Equations are developed that allow the transmissivity and storage coefficient of an aquifer to be determined from recovery data taken from an observation well located at an arbitrary distance from the pumped well without the use of antecedent drawdown data. The fundamental result is in the form of a series based on the Theis recovery equation and up to the number of terms given is exact. The assumptions of radial flow in a confined aquifer that is homogeneous, isotropic, and semi-infinite, which are implicit in the Theis development, are, of course, made in the current work as well. Two numerical examples using actual field data are given.

74:02F-021
NITROGEN CONTENT OF SHALLOW GROUND WATER IN THE NORTH CAROLINA COASTAL PLAIN,
Gilliam, J.W., Daniels, R.B., and Lutz, J.F.
North Carolina State University, Department of Soil Science.
Journal of Environmental Quality, Vol. 3, No. 2, p 147-151, April-June, 1974.
2 fig, 2 tab, 14 ref.
(See 74:05B-054)

## Section VI

## WATER CYCLE

### WATER IN SOILS (GROUP 02G)

74:02G-001
APPROXIMATING SOIL MOISTURE CHARACTERISTICS FROM LIMITED DATA: EMPIRICAL EVIDENCE AND TENTATIVE MODEL,
McQueen, I.S. and Miller, R.F.
Geological Survey, Denver, Colorado, Water Resources Division.
Water Resources Research, Vol. 10, No. 3, p 521-527, June 1974. 6 fig, 43 ref.

Descriptors: *Soil moisture, *Moisture content, Adsorption, Capillary action, Equations, Moisture tension, *Moisture stress.

The soil moisture characteristic can be approximated from limited data as a composite of segments that are simple logarithmic relations. From available data, three segments are evident: (1) a capillary segment from saturation to pF 2.5, (2) an absorbed film segment covering the stress range from about pF 2.5 to about 5.0, and (3) a tightly absorbed segment that extends from pF 5.0 to 7.0.

74:02G-002
DETERMINATION OF DISPERSION AND NONLINEAR ADSORPTION PARAMETERS FOR FLOW IN POROUS MEDIA,
Gupta, S.P. and Greenkorn, R.A.
Purdue University, Lafayette, Indiana, School of Chemical Engineering.
Water Resources Research, Vol. 10, No. 4, p 839-846, August 1974, 10 fig, 3 tab, 19 ref.

Descriptors: *Dispersion, *Adsorption, *Porous media, Groundwater movement, Permeability, Isotherms, Nitrates, Phosphates.

Ottawa washed sand mixed with 0.0-7.5% kaolin clay was used to determine dispersion and nonlinear adsorption parameters during flow through porous media. The ions considered were nitrate for the nonadsorbing species and phosphate for the adsorbing species. A one-dimensional linear model with a longitudinal dispersion coefficient was used, and the dispersion coefficient was determined by least squares fit. The dispersion coefficients were correlated with dispersivity models based on kinematic viscosity and powers of velocity and Reynolds number. The velocity exponent seemed independent of clay content, whereas the model coefficients increased approximately linearly with clay content. The static adsorption data suggest a Freundlich isotherm. The principle of linear superposition was assumed for dispersion and adsorption to estimate the dynamic parameters. The adsorption parameter for the linear model was approximately linear with clay content. The two adsorption parameters for the nonlinear model were highly correlated and cannot be estimated simultaneously from dynamic measurements alone. The linear model described the movement of phosphate ions adequately for the medium considered. However, for a natural system in which clay content is high and phosphate ion concentration is low one would expect better data from the generalized nonlinear model.

74:02G-003
TWO-DIMENSIONAL SEEPAGE IN LAYERED SOIL-DESTABILIZING EFFECTS OF FLOWS WITH AN UNSTEADY FREE SURFACE,
Dicker, D. and Babu, D.K.

New York State University, Stony Brook.
Water Resources Research, Vol. 10, No. 4, p 801-809, August 1974. 5 fig, 8 ref, 1 append.

Descriptors: *Soil stability, *Seepage, *Unsteady flow, *Free surface, *Landslides, Groundwater, Soil pressure, Soil water, Soil water movement, Soil moisture, Soil investigations, Soil mechanics, Soil properties, Mathematical studies, Mathematics, Mathematical models.

An analytic study was made about the destabilizing effects of a prolonged rainfall over the sides of a long symmetric hill. The assumptions underlying the analysis were (1) the soil consisted of layers parallel to the hillslope, (2) the flow domain was bounded from below by an unknown free surface, and (3) this free boundary moves downward with passage of time. The resulting flow pattern was therefore time dependent. The motion is described by Darcy's law as applied to a saturated porous medium having variable conductivity. Perturbation techniques were applied in constructing the solution to this nonlinear problem. For certain portions of the flow region the pertubation becomes singular, and the singularities were removed by the methods of matched asymptotic expansions. Properties of singular integrals with Cauchy kernels were employed in certain quantitative estimates. Only the first-order effects are presented here. It was shown that one large-time effect of prolonged rainfall is to generate outward horizontal velocity components in the distant regions of the slope; these components grow in time. It is known in soil mechanics that such tendencies to outward flow have serious destabilizing effects on the soil slope. This paper demonstrates that the underlying causes for such disasters as landslides can be traced in a significant fashion to the hydrodynamic nature of the seepage that evolves naturally as a result of prolonged rainfall.

74:02G-004
SEEPAGE THROUGH A HILLSIDE: THE STEADY WATER TABLE,
Warrick, A.W. and Lomen, D.O.
Arizona University, Tucson, Department of Soils, Water and Engineering.
Water Resources Research, Vol. 10, No. 2, p 279-283, April 1974. 3 fig, 1 tab, 12 ref.

Descriptors: *Seepage, *Groundwater movement, *Water table, Mathematical studies, Slopes, Topography, Hydraulic conductivity.

An analytical solution is given for seepage through a hillside in which a curved water table is maintained by steady percolating water. The two-dimensional surface is assumed to be a straight slope from the base to a seepage point but may be irregular at higher elevations. Conformal transformations determine seepage elevations and water table profiles as a function of the seepage rate and the slope. For small slopes and small percolation rates the seepage elevation is equal to the rainfall rate times the width of the slope divided by the saturated hydraulic conductivity.

74:02G-005
SALT DISPLACEMENT INTO DRAIN TILES UNDER PONDED LEACHING,
Miyamoto, S. and Warrick, A.W.
Arizona University, Tucson, Department of Soils, Water and Engineering.
Water Resources Research, Vol. 10, No. 2, p 275-278, April 1974. 6 fig, 1 tab, 7 ref.

Descriptors: *Leaching, *Soil water movement, *Tile drainage, Infiltration, Mathematical models, Saturated flow, Saline water, Path of pollutants.

Steady state piston-type displacement into drain tiles when the ground surface is partially covered by an impermeable material or by ponded water away from the drains was analyzed mathematically. By preventing the water from infiltrating directly over the drains a more uniform leaching pattern is attained. The result is to reduce the water required for leaching to the depth of drains by as much as one half. Experimental data obtained from sand tank models support this prediction

74:02G-006
ANION EXCLUSION AND COUPLING EFFECTS IN NONSTEADY TRANSPORT THROUGH UNSATURATED SOILS: II. LABORATORY AND NUMERICAL EXPERIMENTS,
Bresler, E. and Laufer, A.
Agricultural Research Organization, Bet-Dagan, Israel, Department of Soil Physics,
Soil Science Society of America Proceedings, Vol. 38, No. 2, p 213-218, March-April 1974. 8 fig, 1 tab, 11 ref.

Descriptors: *Ion transport, *Leaching, *Soil water movement, Osmosis, Dispersion, Convection, Ion exchange, Chlorides, Mathematical models, Numerical analysis.

A numerical model for the simultaneous transport of anions and water was compared with measured chloride and water flow data. Laboratory soil-column experiments were conducted under conditions of infiltration, redistribution, and evaporation of water in the upper part of the soil profile. The effects of convection, ionic diffusion, mechanical dispersion, anion exclusion and water flow in response to salt concentration gradients were considered jointly. The agreement between theory and experiment, as expressed by flow into and out of the soil-column and by water content and salt distribution profiles, was generally good. The results were relatively insensitive to anion exclusion and osmotic effects. Estimates of dispersivity as obtained from miscible displacement experiments were sufficient for prediction. For the conditions studied, osmotic gradients and anion exclusion effects are of minor importance.

74:02G-007
SOIL WATER CONTENT: MICROWAVE OVEN METHOD,
Miller, R.J., Smith, R.B., and Biggar, J.W.
California University, Davis, Department of Water Science and Engineering.
Soil Science Society of America Proceedings, Vol. 38, No. 3, p 535-537, May-June 1974. 2 fig, 3 tab, 6 ref.

Descriptors: *Moisture content, *Soil moisture, *Microwaves, *Drying, Laboratory tests.

The moisture content of soils may be determined rapidly with a microwave technique. Equations are given for estimating soil drying times for two soils of different texture at different moisture contents and for different sample sizes. Drying soil by microwave oven may also be useful as a method for soil preparation prior to chemical analyses.

74:02G-008
INFLUENCE OF ANTECEDENT SOIL MOISTURE SUCTION ON SATURATED HYDRAULIC CONDUCTIVITY OF SOILS,
Gerard, C.J.
Texas Agricultural Experiment Station, Weslaco.
Soil Science Society of America Proceedings, Vol. 38, No. 3, p 506-509, May-June 1974. 6 fig, 4 tab, 5 ref.

Descriptors: *Hydraulic conductivity, *Antecedent moisture content, *Soil water movement, *Moisture tension, Saturated flow, Soil gases, Carbon dioxide, Wetting.

The influence of antecedent soil moisture suction on saturated hydraulic conductivities of soils was studied. Saturated hydraulic conductivity of a soil is a dynamic property which is markedly influenced by antecedent soil moisture suction. Antecedent soil moisture of 0.33 bar suction, such as is often practiced with trickle irrigation, caused marked reduction in the ability of soil to conduct of water. Gases produced by microorganisms as low suction, their subsequent entrapment, and their influence on soil macrovoids are largely responsible for reduction in ability of soil to conduct water. Reduction of effective soil macrovoids by microbial growth, flowing water, and soil moisture suction can also reduce soil permeability. Soil moisture management can influence the ability of soil to conduct water.

74:02G-009
TIME-DEPENDENT LINEARIZED INFILTRATION. I. POINT SOURCES,
Warrick, A.W.
Arizona University, Tucson, Department of Soils, Water and Engineering.
Soil Science Society of America Proceedings, Vol. 38, No. 3, p 383-386, May-June 1974. 4 fig, 12 ref.

Descriptors: *Soil water movement, *Infiltration, *Unsaturated flow, Equations, Soil moisture, Wetting, Irrigation.

Soil water flow from a point source as analyzed using a linearized form of the moisture flow equation. Time-dependence was assumed with the results simplifying to those for steady-state conditions. Discrete time-distributed inputs such as for trickle or high frequency irrigation are amenable to solution. Numerical simulations include the advance of a wetting front during infiltration, moisture variation resulting from a cyclic input as during irrigation, and the matric flux potential field for a two-source problem.

74:02G-010
MEASUREMENT OF HYDRAULIC CONDUCTIVITY BY MEANS OF STEADY, SPHERICALLY SYMMETRIC FLOWS,
Dirksen, C.
Agricultural Research Service, Madison, Wisconsin, Soil and Water Conservation Research Division.
Soil Science Society of America Proceedings, Vol. 38, No. 1, p 3-8, January-February 1974. 5 fig, 1 tab, 20 ref.

Descriptors: *Hydraulic conductivity, *Unsaturated flow, *Tensiometers, *Soil water movement, Instrumentation, Tension, Infiltration, Percolation, Pressure head, Moisture content.

The dependence of hydraulic conductivity upon pressure head can be determined from a series of steady, spherically symmetric flows: at any point the hydraulic conductivity is equal to the rate of change of the steady flux per unit solid angle with respect to the pressure head of that point, divided by its radial distance from the center of the water source. This method is useful for in-situ measurements in the field because it requires only one controlled boundary condition, and does not require one-dimensional flow. Hydraulic conductivity values derived from the pressure head in the source cavity in field tests were the same as those derived from tensiometer measurements near the source. A range of hydraulic conductivity values can be obtained faster with a series of different, steady pressure heads in the source cavity, rather than by measurements on a series of tensiometers located at several distances from the source. Gravity tends to distort the spherical symmetry of the flow. For most soils the effect of gravity near the cavity is small enough to obtain satisfactory hydraulic conductivity values. Gravity has no effect on the pressure head distribution directly below the cavity, suggesting that this is a preferred location for tensiometers. The analytical solution obtains the hydraulic conductivity in an exact manner for any position. The radius of the cavity should be kept as small as possible.

74:02G-011
FLUX-GRADIENT RELATIONSHIPS AND SOIL-WATER DIFFUSIVITY FROM CURVES OF WATER CONTENT VERSUS TIME,
Nofziger, D.L., Ahuja, L.R. and Swartzendruber, D.
Purdue University, Lafayette, Indiana, Department of Agronomy.
Soil Science Society of America Proceedings, Vol. 38, No. 1, p 17-23, January-February 1974. 6 fig, 11 ref.

Descriptors: *Soil water movement, *Unsaturated flow, Seepage, Percolation, Equations, Wetting, *Diffusivity, Diffusion.

Direct analysis of a family of curves of soil-water content versus time at different fixed positions enables assessment of the flux-gradient relationship prior to the calculation of soil-water diffusivity. The method was evaluated on both smooth and random-error data generated from the solution of the horizontal soil-water intake problem with a known diffusivity function. Interpolation, differentiation, and integration were carried out by least-squares curve fitting based on the two recently developed techniques of parabolic splines and sliding parabolas. Results were excellent for both smooth and random-error input data, whether in terms of recovering the original known diffusivity function, assessing the nature of the flux-gradient relationship, or in making the numerous checks and validations at various intermediate stages of computation. The method applies for any horizontal soil-wetting process independently of the specific boundary conditions, including water entry through a nonzero inlet resistance. It should be adaptable to horizontal dewatering, and extendable to vertical flow.

74:02G-012
GAMMA RADIATION MEASUREMENTS OF BULK DENSITY CHANGES IN A SOIL PEDON FOLLOWING IRRIGATION,
Reginato, R.J.
Agricultural Research Service, Phoenix, Arizona, Water Conservation Laboratory.
Soil Science Society of America Proceedings, Vol. 38, No. 1, p 24-29, January-February 1974. 3 fig, 4 tab, 14 ref.

Descriptors: *Bulk density, *Expansive soils, *Nuclear moisture meters, Gamma rays, Irrigation effects, Soil physical properties.

Bulk density in a soil pedon was measured with a gamma-ray transmission technique utilizing Cs-137 and Am-241. Both gamma-ray sources could not be used simultaneously. By alternating sources for each scan down the soil profile, bulk density was found to decrease in the top 6 cm of soil about 30 minutes after water was ponded on the soil surface. As soon as the water drained from the surface, bulk density values approached preirrigation levels. Changes in height of the soil surface upon irrigation corresponded with changes in bulk density.

74:02G-013
THERMODYNAMICS OF ION EXCHANGE,
Ravina, I. and DeBock, J.
Technion - Israel Institute of Technology, Haifa, Department of Agricultural Engineering.
Soil Science Society of America Proceedings, Vol. 38, No. 1, p 45-49, January-February 1974. 2 tab, 13 ref.

Descriptors: *Ion exchange, *Clays, *Water chemistry, Thermodynamics, Sorption, Cation exchange, Chemical potential, Ionization, Free energy.

A local formulation of nonequilibrium thermodynamics was used to define the electrochemical potentials in the ion-clay-water system, thus enabling development of an improved nonempirical approach to cation-exchange processes. The presence of the electrical field in the system is expressed by a proportional increase of the pressure in the double layer. The effect of the electrical field on the chemical potentials of the exchangeable cations is divided into the common electrostatic term and a term dependent on their polarizabilities. For systems containing a mixture of monovalent ions the electrostatic effect of the electrical field is the same for each of the exchangeable cations. Using values of the polarizabilities and intrinsic volumes of the alkali metal cations, the free energies of exchange with sodium in montmorillonite were calculated. The calculated free energies were in good agreement with experimental values.

74:02G-014
SUBSURFACE DRAINAGE SOLUTIONS BY GALERKIN'S METHOD,
Dass, P. and Morel-Seytoux, H.J.
Colorado State University, Fort Collins, Department of Civil Engineering.
Proceedings of ASCE, Journal of the Irrigation and Drainage Division, Vol. 100, No. IR1, Proc Paper 10397, March 1974, p 1-15, 8 fig, 1 tab, 15 ref.

Descriptors: *Aquifers, Water table, *Drainage, *Subsurface drainage, Methodology, *Design Criteria.

For the solution of drainage problems a linearized form of Boussinesq's equation is often used. To improve the design, higher order approximations have been used. A variation of Galerkin's method is used to solve the nonlinear Boussinesq equation. By comparison it is found that the linearized method, when the drawdown to aquifer depth ratio, H/d, becomes large, provides too optimistic designs. The design criteria based on the linearized Boussinesq equation overestimates the rate of drainage for two reasons: (1) They do not account for important nonlinear effects; and (2) they do not account for the delaying effect of the unsaturated flow condition above the water table. The use of Galerkin's method makes it possible to account for the nonlinear effect which is quite significant.

74:02G-015
DERIVATION OF AN EQUATION OF INFILTRATION,
Morel-Seytoux, H.J. and Khanji, J.
Universite Scientifique et Medicale de Grenoble (France), Institute de Mecanique.
Water Resources Research, Vol. 10, No. 4, p 795-800, August 1974. 3 fig, 1 tab, 15 ref.

Descriptors: *Infiltration rates, *Unsaturated flow, *Capillary conductivity, *Permeability, Percolation, Hydraulic conductivity.

A precise physical meaning was shown for the emperical parameters developed by Green and Ampt (1911). The functional relation between the effective capillary head and the initial water content was obtained. In addition, it was shown that Green and Ampt's assumption of a front separating a saturated zone from the zone at the initial water content can lead to errors of prediction of 10-70 percent. The formulas developed are both simple and accurate and of practical value to the hydrologist.

74:02G-016
A PREDICTOR-CORRECTOR METHOD FOR SOLVING THE CONVECTION-DISPERSION EQUATION FOR ADSORPTION IN POROUS MEDIA,
Tagamets, T. and Sternberg, Y.M.
Maryland University, College Park, Department of Civil Engineering.
Water Resources Research, Vol 10, No 5, p 1003-1011, October 1974, 9 fig, 23 ref.

Descriptors: *Adsorption, *Convection, *Dispersion, Numerical analysis, Fluid movement, Porous media, Saturated flow, Equations, Mathematical models, Mass transfer, Isotherms, Finite element analysis.

The on-dimensional convection-dispersion equation subject to a nonlinear adsorption isotherm was formulated and solved by using a predictor-corrector finite difference scheme. The effects of convection, dispersion, and adsorption were illustrated for some typical values of variable encountered in 'real systems'. A comparison between the numerical results and some experimental data was also presented.

74:02G-017
A COUPLED HEAT AND MOISTURE TRANSPORT MODEL FOR ARCTIC SOILS,
Guymon, G.L. and Luthin, J.N.
Alaska University, College, Institute of Water Resources.
Water Resources Research, Vol. 10, No. 5, p 995-1001, October 1974. 1 fig, 27 ref.

Descriptors: *Arctic, *Permafrost, *Soil moisture, *Soil water movement, *Thermal properties, *Frozen soils, Alaska, Thawing, Freezing, Tundra, Hydraulic conductivity, Frost heaving, Darcys law, Conduction, Computer models, Equations, Numerical analysis.

The thermal and moisture regimes of arctic and subarctic soils act in parallel in a complex manner and must be considered together. The problem of moisture movement and storage in these soils is complicated by water undergoing a phase change during freezing and thawing and by the presence of ice-rich permafrost. A one-dimensional model of these processes was developed based on an equivalent quasi-linear variational functional for the Richards equation and the heat conduction equation including convective components. The variational functional was solved by a finite element analog. Convergence and stability were investigated, and it was concluded that the numerical procedure is convergent and stable in general.

74:02G-018
PERMEABILITY OF UNSATURATED FIELD SOILS CALCULATED FROM LABORATORY DESATURATION DATA,
Sinclair, L.R., Fitzsimmons, D.W. and Bloomsburg, G.L.
Florida University, Sanford, Agricultural Research and Education Center.
Transactions of the American Society of Civil Engineers, Vol. 17, No. 3, p 399-405, May-June 1974. 11 fig, 1 tab, 26 ref.

Descriptors: *Porous media, *Permeability, *Unsaturated flow, *Laboratory tests, Soil water, Capillary water, Soils, Agriculture, Soil tests, Hydraulic conductivity, Pervious soils, Pores, Soil water movement, Porosity, Testing procedures.

A method of calculating the permeability of partially saturated field soils from experimentally determined capillary pressure head-saturation relationships developed. The method involved the use of a Burdine-type equation to calculate the relative permeability values which were expressed as a function of average values of the square of the pore radius calculated from the pore-size distribution of the soil using a statistical approach. The pore-size distribution was determined from the capillary pressure head-saturation relationship for the soil. The method was evaluated by comparing experimental capillary pressure head-permeability relationships for seven soils with similar relationships calculated from experimentally determined capillary pressure head-saturation relationships. These comparisons were made with relationships obtained for both disturbed and undisturbed samples of each soil. In general, the calculated relationships compared favorably with the experimentally determined relationships. Very close agreement was found between experimental and calculated capillary pressure head-permeability relationships when the data were scaled by dividing permeability and capillary pressure head values by the saturated permeability and bubbling pressure head of the soil, respectively. When the data were scaled in this way, the capillary pressure head-permeability relationships calculated for both undisturbed and disturbed samples of a soil were essentially the same.

74:02G-019
PROCEEDINGS OF THE SECOND INTERNATIONAL DRIP IRRIGATION CONGRESS,
Second International Drip Irrigation Congress,
California University and United States Department of Agriculture, Agriculture Research Service.
Second International Drip Irrigation Congress, July 7-14, 1974, San Diego, California.
(See 74:03F-006)

74:02G-020
HIGH ELECTROLYTE WATER FOR RECLAIMING SLOWLY PERMEABLE SOILS,
Rahman, M.A., Hiler, E.A., and Runkles, J.R.
Texas A&M University, College Station.
Transactions of the American Society of Agricultural Engineers, Vol. 17, No. 1, p 129-132, January-February 1974. 7 fig, 2 tab, 11 ref.

Descriptors: *Infiltration, *Infiltration rates, *Hydraulic conductivity, Electrolytes, Soil investigations, Soil management, Soil physical properties, Soil treatment, Soil water movement, Permeability, Agriculture.

Reclamation processes in a slowly permeable, mildly sodic, low electrolyte, humid soil were studied using different ionic compositions and concentrations of electrolyte waters. The method utilized for this soil consisted of increasing soil hydraulic conductivity with additions in increasing concentration of electrolyte water and then leaching out salts with decreasing concentrations while maintaining the increased hydraulic conductivity. It can be concluded that electrolyte waters applied in increasing followed by decreasing concentrations were utilized successfully for reclaiming this soil. The soil intake rates and hydraulic conductivities were increased very substantially. Further applied research and field trials with similar soils seem justified based on the findings.

74:02G-021
POWDERED METAL PLATES FOR CONSTRUCTING UNSATURATED FLOW CELLS,
Bianchi, W.C.
United States Department of Agriculture, Agricultural Research Service, Fresno, California, Water Management Research.
Soil Science Society of America Proceedings, Vol. 38, No. 4, p 683-684, July-August, 1974. 3 fig, 1 tab, 4 ref.

Descriptors: *Unsaturated flow, Flow measurement, Groundwater recharge, Groundwater movement.

Described is the theoretical design, construction and observed characteristics of sintered stainless steel powdered metal plates which could be used in control sections of an unsaturated flow cell.

74:02G-022
SMALL TENSIOMETERS FOR FIELD AND LABORATORY STUDIES,
Rogers, J.S.
United States Department of Agriculture, Agricultural Research Service, Gainesville, Flordia.
Soil Science Society of America Proceedings, Vol. 38, No. 4, p 690-691, July-August, 1974. 1 fig.

Descriptors: *Tensiometers, Laboratory equipment, Soil moisture, Soil water, Soil investigations.

A small tensiometer was constructed and used in field and laboratory studies. The units are suitable only for low suctions, but have the fast response time that is desirable for measuring short-term changes in field and laboratory studies of drainage. Several tensiometers have been in use for over 4 years and continue to perform very satisfactorily.

74:02G-023
DETERMINING EFFECTIVE SOIL WATER DIFFUSIVITIES FROM ONE-STEP OUTFLOW EXPERIMENTS,
Gupta, S.C., Farrell, D.A., and Larson, W.E.
Minnesota University, St. Paul.
Soil Science Society of America Proceedings, Vol. 38, No. 5, p 710-716, September-October, 1974. 7 fig, 15 ref. append.

Descriptors: Diffusivity, Methodooogy, Soil water, Soil water movement, Soil properties, Computers.

A method is developed whereby effective or weighted mean diffusivity, D, can be estimated by using outflow data. These estimates can further be analyzed for soil water diffusivity, D theta, with the help of a step-wise function and the relationship given by Crank (1956). The suggested procedure for estimating soil water diffusivity is more accurate than previous methods because no assumption of constant diffusivity either over the pressure increment or over the length of the soil core is required. Moreover, the procedure does not use the early part of the outflow curve and thus reduces the effect of membrane impedance on the estimates of D theta. The method was tested by simulating outflow experiments on a digital computer, and using data obtained to calculate diffusivities. Our estimates of diffusivity were in better agreement with the actual diffusivities than those obtained with the earlier "one-step" method.

74:02G-024
UNSATURATED HYDRAULIC CONDUCTIVITY FROM CUMULATIVE INFLOW DATA,
Ahuja, L.R.
Hawaii University, Honolulu, Department of A,ronomy and Soil Science.
Soil Science Society of America Proceedings, Vol. 38, No. 5, p 695-699, September-October, 1974. 6 fig, 13 ref.

Descriptors: *Hydraulic conductivity, Infiltration, Diffusivity, Soil properties.

A method of determining the wetting-phase unsaturated hydraulic conductivity K theta from the data of cululative inflow into a uniform soil core when water enters through a porous plate of high hydraulic resistance is described and evaluated. The method is based on piecewise application of the Green and Ampt (1911) approach to the above process of infiltration. The K theta determined by this technique from the numerical-solution inflow data of Yolo light clay were within 20% of the K theta values actually used in obtaining the numerical solution in two different cases of hydraulic resistance. Similar analysis of the experimental inflow data of Salkum silty clay loam for four different hydraulic resistances yielded the K theta data which closely agreed with the K theta values determined by detailed analysis of the soil-water content transients.

74:02G-025
**STEADY FLOWS OF WATER AND SALT IN UNIFORM SOIL PROFILES WITH PLANT ROOTS,**
**Raats, P.A.C.**
U.S. Salinity Laboratory, Riverside, California.
Soil Science Society of America Proceedings, Vol. 38, No. 5, p 717-722,
September-October, 1974. 8 fig, 20 ref.

Descriptors: *Soil water movement, Root system, Root zone, Pressure head, Hudraulic conductivity, Soil-water-plant relationships.

Steady upward and downward flows of water in the presence of uptake of water by plant roots are analyzed. Qualitative features of possible pressure head, total head, and water content profiles for steady conditions are discussed. Specific calculations are based upon an exponential increase of the hydraulic conductivity with the pressure head and an exponential decrease of the rate of uptake with depth. For downward flows, the distribution of the matric flux potential can be expressed as a function of the rate of infiltration, the leaching fraction, and two parameters cahracterizing the soil and the uptake distribution, respectively. Although the water content on the root zone may be nearly uniform, the matric component of the flux may be significant. For upward flows, the distribution of the matric flux potential can be expressed as a function of the rate of infiltration, the rate of transpiration, the hydraulic conductivity of the saturated soil and the same two parameters characterizing the soil and the uptake distribution. The depth at which the flux vanishes, the minimum value of the matric flux potential for a given depth of the water table, and the maximum depth of the water table are evaluated. Finally, neglecting the effects of salt precipitation and dissolution and of diffusion and dispersion, the distribution of salts associated with the steady downward flows is evaluated.

74:02G- 026
TWO-DIMENSIONAL DISPLACEMENT INTO OR FROM WATER-FILLED DITCHES,
Miyamoto, S. and Warrick, A.W.
Arizona University, Tucson, Department of Soils, Water and Engineering.
Soil Science Society of America Proceedings, Vol. 38, No. 5, p 723-726,
September-October, 1974. 5 fig, 1 tab, 11 ref, append.

Descriptors: Soil water movement, Leaching, Drainage water, Water quality, Daline water intrusion, Fertilizers.

Piston-type displacement of solutes for steady-state saturated flow into or from water-filled ditches is analyzed mathematically and by a sand-tank model. The displacement front onto the drains advances much faster near the drains than in the region midway between them. The presence of an impermeable sublayer accentuates this trend. The front becomes nearly horizontal for a wider surface impermeable spoil bank or if water is ponded away from the drains. Such a spoil bank may be useful for reducing the amount of water required to leach salts or for minimizing the loss of water-applied fertilizers into drains. The displacement front for water moving from the ditches into a field (such as for salt intrusion from open ditches) advances in an ellipsoidal pattern. The analysis is also useful for prediction the displacement patterns for localized initial solute distributions. Experimental data obtained from a sand-tank model agree with the predicted fronts.

74:02G-027
CHLORIDE AND TRITIATED WATER FLOW IN DISTURBED AND UNDISTURBED SOIL CORES,
McMahon, M.A. and Thomas, G.W.
Kentucky University, Lexington, Department of Agronomy.
Soil science Society of America Proceedings, Vol. 38, No. 5, p 727-732,
September-October, 1974. 6 fig, 4 tab, 13 ref.

Descriptors: Soil water movement, Soil properties, Water chemistry, Chlorides, Nitrates, Soil investigations, Soil physics, Anions.

Columns of disturbed and undisturbed Eden, Maury, and Pembroke soils were eluded with CaCl2 in tritiated water. The chloride was used as a substitute for nitrate since it is not affected biologically. The experiments were carried out to investigate the effects of natural soil structure on the flow of water and chloride. In all three soils flow was less stable in the undisturbed cores judging from the shape of the curve and the points of initial tritiated water and chloride breakthrough. Chloride moved through the undisturbed Eden and Maury soils faster than through the disturbed columns. Both soils exclude anions to a significant extent. In the Pembroke soil, which adsorbs anions, the chloride was retarded in the undisturbed column as compared to the disturbed column. The results suggest that field movement fo water and anions is not described very well by columns of disturbed, packed soils.

74:02G-028
TWO-DIMENSIONAL WATER INFILTRATION FROM A TRENCH IN UNSATURATED SOILS,
Sawhney, B.L. and Parlange, J.-Y.
Connecticut Agricultural Experiment Station, New Haven.
Soil Science Society of Amercia Proceedings, Vol. 38, No. 6, p 867-871,
November-December, 1974. 8 fig, 2 tab, 10 ref.
(See 74:03F-137)

74:02G-029
DETERMINATION OF WETTING FRONT SUCTION IN THE GREEN-AMPT EQUATION,
Mein, R.G. and Farrell, D.A.
Monash University, Victoria, Australia.
Soil Science Society of America Proceedings, Vol. 38, No. 6, p 872-876,
November-December, 1974. 3 fig, 4 tab, 10 ref.

Descriptors: *Infiltration, Theoretical analysis, Hydraulic conductivity, Capillary action, Soil water movement, Wetting, Soil water, Soil investigations.

Interest in the Green-Ampt equation to predict infiltration rates into uniform and layered soils has increased in recent years. The work reported here is a study of the theoretical justification of determining the suction (at the wetting front) parameter in the equation from the hydraulic conductivity versus capillary suction relationship for the soil. It is shown that the wetting from suction so determined and used in a form of the Green-Ampt equation which allows for the surface boundary condition initially being one of constant flux gives predictions of infiltration volumes comparable to those determined by numerical solution of the complex partial-differential equation of moisture flow.

74:02G-030
NOMOGRAPHIC INTERPRETATION OF WATER ABSORPTION DATA IN TERMS OF A TWO-PARAMETRIC DIFFUSIVITY-WATER CONTENT FUNCTION,
Stroosnijder, L. and Bolt, G.H.
State Agricultural University, Wageningen, The Netherlands, Dept. of Soils and Fertilizers.
Soil Science Society of America Proceedings, Vol. 38, No. 6, p 876-880,
November-December, 1974. 5 fig, 2 tab, 13 ref.

Descriptors: Diffusivity, Moisture content, Wetting.

An exponential extrapolation of a set of experimentally determined diffusivities, D as a function of water content, theta, into the region near saturation lead to an underestimate of the water absorption. A two-parametric expression for the diffisivity as a function of theta, as proposed by Ahuja et al. (1972), is used to construct a nomogram. This provides a connection between the standardized D-theta relationships according to Ahuja et al. and certain "integral" properties of the absorption wetting process viz. the sorptivity and a shape factor of the wetting front. Good agreement is obtained between experimentally determined diffusivity values and the values derived from the nomographical interpretation of water absorption data. The present approach also lends itself to the construction of families of scaled wetting curves. Thus absorption behavior for different (uniform) initial moisture contents could be predicted adequately.

74:02G-031
UNSTEADY, UNSATURATED, N-DIMENSIONAL MOISTURE FLOW IN SOIL: A COMPUTER SIMULATION PROGRAM,
Van der Ploeg, R.R. and Benecke, P.
Georg-August University, Goettingen, West Germany.
Soil Science Society of America Proceedings, Vol. 38, No. 6, p 881-884, November-December, 1974. 7 fig, 1 tab, 15 ref.
(See 74:03F-139)

74:02G-032
LIMITATIONS OF THE INSTANTANEOUS PROFILE METHOD FOR FIELD MEASUREMENT OF UNSATURATED HYDRAULIC CONDUCTIVITY,
Baker, F.G., Veneman, P.L.M., and Bouma, J.
Wisconsin University, Madison, Department of Soil Science.
Soil Science Society of America Proceedings, Vol. 38, No. 6, p 885-888, November-December, 1974. 4 fig, 13 ref.

Descriptors: *Hydraulic conductivity, Soil water movement, Tensiometer, Moisture content, Soil water, Soil tests, Soil investigations.

Technical problems and soil profile characteristics may limit the applicability of the instantaneous profile method for field measurement of unsaturated hydraulic conductivities. A modified procedure for tensiometer installation and different methods for measuring moisture contents are discussed. Good agreement was found between moisture contents determined in situ with the neutron-probe and those indirectly derived from moisture retention curves obtained from measurements of large core samples in a closed assembly. Sloping soils with slowly permeable horizons or with lateral water movement cannot be characterized adequately with this method. The use of the crust test procedure is recommended.

74:02G-033
KINETIC AND EQUILIBRIUM STUDIES OF BORON DESORPTION FROM SOIL,
Griffin, R.A. and Burau, R.G.
California University, Davis, Department of Soils and Plant Nutrition.
Soil Science Society of America Proceedings, Vol. 38, No. 6, p 892-897, November-December, 1974. 6 fig, 2 tab, 19 ref.

Descriptors: *Boron, Adsorption Kinetics, Soil Texture, Soil chemistry, Soil tests, Soil investigations.

Kinetics of boron desorption from soil were determined using 0.05M manitol solutions to create pseudo first-order reaction conditions. The results showed two separate pseudo first-order reactions and one very slow reaction for which detailed kinetic treatment was not attempted. The relative amount of boron associated with the two fast reactions was indepdendent of soil texture and of initial sample boron content. It was postulated that the two reaction rates were due to desorption from two independent boron retention sites. It was speculated that the two fast reactions were due to desorption from hydroxy iron, magnesium, and aluminum materials in the clay fraction. The third or slowest reaction rate was probably due to diffusion of boron from the interior of clay minerals to solution phase. Equilibrium studies showed that boron desorption followed a 2-site analog of a linear form of a 1-site Langmuir expression. Langmuir adsorption maximum values for each site corroborated those calculated from the kinetic study and supported the multisite interpretation of the kinetic data.

74:02G-034
EFFECT OF SNOW COVER ON UPWARD MOVEMENT OF SOIL MOISTURE,
Peck, E.L.
National Oceanic and Atmospheric Administration, Silver Spring, Maryland.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 100, No. IR4, p 405-412, December, 1974. 2 fig, 15 ref.

Descriptors: Soil water movement, Soil water, Snow, Snow cover, Snowfall, Watershed management.

The information presented in this brief paper is neither sufficient nor conclusive enough to demonstrate that soil moisture and temperature conditions under the late season snow cover are a critical factor in determining the magnitude of the snowmelt runoff. However, the evidence presented is sufficient to show that: (1) Soil moisture under the snow cover in selected areas usually does increase during the winter; and (2) the increase should be considered in predicting the spring runoff. Further research on the magnitude of the effects examined in this paper will probably indicate how conceptual watershed models can be modified to account for the unusual moisture movement.

74:02G-035
FIELD TEST OF SOIL WATER FLUX METERS,
Dirksen, C.
U.S. Salinity Laboratory, Riverside, California.
Transactions of the ASAE, Vol. 17, No. 6, p 1038-1042, November-December, 1974. 4 fig, 1 tab, 5 ref.

Descriptors: *Soil water, *Soil water movement, Soil properties, Soil tests, Tensiometers.

This field test represents an attempt to measure soil water fluxes directly in essentially undisturbed soil. This was accomplished by excavating access holes perpendicularly to the direction of flow with a specially designed apparatus. Filter plates were pressed against undisturbed soil by a spring. Fluxes were measured by adjusting the overall hydraulic head loss across the meters, with a variable hydraulic resistance, to that in the soil nearby. Two flux meters gave realistic results that were generally in good agreement with each other. They reacted rapidly to different hydraulic resistance values consistent with earlier laboratory tests. This is in sharp contrast with an earlier attempt in which the access holes were dug by hand resulting in a complete failure.

74:02G-036
SOME EFFECTS OF SUBIRRIGATION ON BENTGRASS DURING HEAT STRESS IN THE FIELD,
Krans, J.V. and Johnson, G.V.
Arizona University, Tucson, Department of Soils, Water and Engineering.
Agronomy Journal, Vol. 66, No. 4, p 526-630, July-August, 1974. 5 fig, 3 tab, 10 ref.
(See 74:03F-157)

74:02G-037
PROGRESS IN DRAINAGE,
Kuntze, H.
Niedersachsisches Landesamt fur Bodenforschung Ausseninstitut Bremen, F.R. of Germany.
International Commission on Irrigation and Drainage, p 24-26, January 1974.

Descriptors: *Drainage, *Drainage engineering, Drainage practices, Drains, Soil profiles, Automation.

When planning a drainage system, a careful survey and testing of soil profiles and water table conditions should determine the most effective combination of drain spacing, drain depth, kind of pipe and filter-wrap. Then a long useful life can be guaranteed and even difficult soils become suitable for drainage. In the future, the trenchless fully automatic drainage machine will provide further reduction of cost. A variety of filter-wrapped plastic draintubes with defined entrance holes have been adapted to the prevailing soil characteristics of specific drainage areas. This wide range of different kinds of plastic tubes in drainage has considerable advantages over the little variable tile drain.

74:02G-038
REVIEW OF WATERLOGGING AND DRAINAGE PROBLEMS AND THEIR SOLUTIONS IN INDIA,
Framji, K.K.
International Commission on Irrigation and Drainage 48, Nyaya Marg,
Chanakyapuri, New Delhi.
International Commission on Irrigation and Drainage, p 36-41, January, 1974.
13 ref.

Descriptors: *Drainage, *Drainage practices, Water table, Saturated soils, Saturation, Groundwater, Groundwater movement.

The paper reviews the waterlogging that occurred almost everywhere in India on the introduction of canal irrigation and which grew to menacing dimensions in the absence of any in-built anti-waterlogging measures in the irrigation projects. The subsequent drainage provisions and their effects have been examined in retrospect. The causes, effects and extents of waterlogging have been outlined and the important lessons learnt from experience and from the historical studies on waterlogging and drainage have been touched upon with a cautionary note against expectations from transference of knowledge and experience to other problem areas. Research needs for obtaining scientifically precise anti-waterlogging measures and their design criteria have been indicated, but it is concluded that with the modern methods of Systems Approach it should be possible to evolve without waiting for research results, the optimized measures for meeting the required conditions of integration of ground water and surface water uses, and of irrigation and drainage networks for stable ground water conditions at the required degree of relief and for ensuring permanent irrigated agriculture.

74:02G-039
FIELD TEST OF A MODIFIED NUMERICAL MODEL FOR WATER UPTAKE BY ROOT SYSTEMS,
Feddes, R.A., Bresler, E., and Neuman, S.P.
Institute of Soils and Water, Volcani Center, Bet Dagan, Israel, Department of Soil Physics.
Water Resources Research, Vol. 10, No. 6, p 1199-1206, December, 1974. 6 fig,
2 tab, 35 ref.

Descriptors: *Model studies, *Root systems, Evapotranspiration, Root zone, Water balance.

Data obtained from careful water balance studies on water uptake by the roots of red cabbage are compared with results obtained from a modified numerical model of Nimah and Hanks. In the modified model the air dry moisture content at the soil surface may vary with time depending on meteorological conditions. The maximum possible rate of evapotranspiration is calculated by considering both meteorological conditions and crop properties. Data are quoted to suggest that the coefficient of the root sink may sometimes vary exponentially with depth.

74:02G-040
MORE OF AN APPROXIMATE SOLUTION FOR NONLINEAR DIFFUSION,
Brutsaert, W.
Cornell University, Ithaca, New York.
Water Resources Research, Vol. 10, No. 6, p 1251-1252, December, 1974.
11 ref.

Descriptors: *Diffusion, Mathematical studies, Soil water, Soil water movement.

A method of solution developed earlier (1970) for a diffusivity, that is, a power function of concentration, is shown to be more generally applicable. One of the conditions of its applicability is the existence of a sharp diffusing front. As an illustration the solution is worked out herein for a diffusivity that has been useful in the analysis of soil water problems.

74:02G-041
NITRATE CONCENTRATIONS IN DEEP SOIL CORES AS RELATED TO SOIL PROFILE CHARACTERISTICS,
Lund, L.J., Adriano, D.C. and Pratt, P.F.
California University, Riverside, Department of Soil Science and Agricultural Engineering.
Journal of Environmental Quality, Vol. 3, No. 1, p 78-82, January-March, 1974.
2 fig, 5 tab, 15 ref.

Descriptors: *Denitrification, *Nitrates, *Nitrogen, *Soil profiles, *Soil horizons, Soil investigations.

Fifteen sites within a 30-ha study area were studied to determine the effect of soil profile characteristics on nitrate concentrations below the root zone. The N input, crop removal of N, and water management were similar for all sites during the previous 6 years. The soils of the study area were primarily Alfisois and Entisols of fine-loamy, coarse-loamy, sandy and sandy over loamy families. Nitrate concentrations varied between sites and with depth. The average nitrate concentrations below the root zone ranged from 4.9 to 15.3 micro-q when expressed on an oven-dry soil basis. Profile characteristics were significantly correlated with the average nitrate concentrations below the root zone. A regression equation relating average nitrate concentration in the 1.8-8 m depth to control section characteristics explained 86% of the variability of the nitrate concentration and was highly significant. Hence, to minimize ground-water pollution, soil profile characteristics should be considered in selecting land for high N input whether by fertilization or waste disposal.

74:02G-042
NITROGEN RELEASE ASSOCIATED WITH THE DECREASE IN SOIL ORGANIC MATTER IN NEWLY CULTIVATED SOILS,
Reinhorn, T. and Avnimelech, Y.
Israel Institute of Technology, Haifa, Israel, Soils and Fertilizers Laboratory.
Journal of Environmental Quality, Vol. 3, No. 2, p 118-121, April-June, 1974.
2 fig, 2 tab, 18 ref.

Descriptors: *Nitrogen, *Organic matter, *Organic soils, Groundwater, Water quality, Cultivation.

A marked decrease in soil organic matter occurs during the first years following the cultivation of virgin soils. The purpose of this work is to study the release of nitrogen, associated with this process. Technically, this was achieved by a series of comparisons between cultivated plots and adjacent virgin soils. It was found, that in the area under study, the decrease in soil organic nitrogen was rather fast and a steady state was apparently achieved during the first few years. The amount of nitrogen released during this process is up to 9 tons of N/ha. The amount of nitrogen released is linearily related to the initial organic nitrogen content of the soil. In regions where large areas of newly cultivated fields are found, this process may be a major factor responsible for nitrate enrichment of the drainage water.

74:02G-043
FIELD STUDY OF SOLUTE MOVEMENT IN A HIGHLY AGGREGATED OXISOL WITH INTERMITTENT FLOODING: II. PICLORAM,
Rao, P.S.C., Green, R.E., Balasubramanian, V., and Kanehiro, Y.
Hawaii University, Honolulu, Department of Agronomy and Soil Science.
Journal of Environmental Quality, Vol. 3, No. 3, p 197-201, July-September, 1974.
2 fig, 1 tab, 16 ref.

Descriptors: *Pesticides, *Herbicides, Soil chemistry, Water quality, Groundwater, Irrigation, Soil profiles.

Most of the applied herbicide picloram was retained in the top 40-cm depth of the Molokai soil with cumulative applications of 48 to 74 cm water following application of the chemical to the soil surface. Although movement of the picloram peak was retarded more than was anticipated from equilibrium adsorption measurements, a significant fraction of the applied herbicide moved ahead of the peak deep into the profile (down to the 143-cm depth) after a single application of 24-cm water. Rapid flow through macropore sequences combined with temporary retention of picloram in aggregate micropores appear to be responsible for the unusual pattern of movement. Published data for nitrate movement in the same field plots of Molokai soil were compared with picloram movement data to provide a measure of the relative mobility of these solutes. A comparison of the results reported here with published field data of solute leaching in other soils indicated a greater retardation of solute peak movement in Molokai soil than in less aggregated soils.

74:02G-044
NITRATE AND CHLORIDE ACCUMULATION AND DISTRIBUTION IN FERTILIZED TILE-DRAINED SOILS,
Gast, R.G., Nelson, W.W., and MacGregor, J.M.
Minnesota University, St. Paul.
Journal of Environmental Quality, Vol. 3, No. 3, p 209-213, July-September, 1974. 5 fig, 3 tab, 9 ref.

Descriptors: *Nitrates, *Nitrogen, *Denitrification, Leaching, Soil water movement, Fertilizers, Fertilization, Corn, Tile drainage, Drainage, Organic matter.

Results of long term continuous corn studies on tile drained Webster loam in southwest Minnesota show that annual N applications up to 70% greater than N removed in grain are required for maximum yields. The object of the reported study was to establish the relative role of N incorporation into the soil organic matter and/or losses through denitrification, downward leaching, or tile drainage in determining the fate of this fertilizer-N added above that removed in corn grain. Nitrate and chloride accumulations and distributions were determined in a Webster loam and Waldorf silty clay loam profiles after long term fertilization for continuous corn. Concentrations in the profiles were determined at 0.3 m depth intervals and at increasing distances from tile lines.

74:02G-045
THE EFFECT OF LARGE APPLICATION OF MANURE ON MOVEMENT OF NITRATE AND CARBON IN AN IRRIGATED DESERT SOIL,
Meek, B.D., MacKenzie, A.J., Donovan, T.J., and Spencer, W.F.
Imperial Valley Conservation Research Center, Brawley, California.
Journal of Environmental Quality, Vol. 3, No. 3, p 253-258, July-September, 1974. 9 fig, 3 tab, 8 ref.

Descriptors: *Feedlots, Soil investigation, Irrigation, Nitrate, Carbon, Manganese, Denitrification, Soil chemistry, Soil profile.

Feedlot manure was applied in the field at rates of 0, 45, 90, 180, and 360 metric tons/ha to a Holtville clay under irrigated conditions. Holtville clay is a soil with restricted internal drainage. Ceramic cups were installed at various depths in the soil profile to monitor the movement of manganese, nitrate, and soluble organic carbon. The manure greatly increased the amount of soluble organic carbon in the soil solution. An increase in the manure application rate to 180 or 360 metric tons/ha increased the nitrate in the soil solution at 20 and 40 cm, but there were only small differences at 80 and 140 cm. The lack of movement of nitrate to the 80-cm depth for the high rates of manure application appeared to be due to denitrification, because high nitrate levels were present in the surface soil and sufficient water was applied to leach to this depth.

74:02G-046
COLUMN STUDIES OF SOIL CLOGGING IN A SLOWLY PERMEABLE SOIL AS A FUNCTION OF EFFLUENT QUALITY,
Daniel, T.C. and Bouma, J.
Wisconsin University, Madison, Department of Soil Science.
Journal of Environmental Quality, Vol. 3, No. 4, p 321-326, October-December, 1974. 8 fig, 2 tab, 25 ref.

Descriptors: *Septic tanks, *Soil disposal fields, *Clogging, *Effluents, Chemical oxygen demand, Biochemical oxygen demand, Soil properties, Soil investigations, Soil structure, Soil water movement.

Clogging as a function of effluent quality was investigated in cores of the very slowly permeable Almena silt loam soil which offers problems for conventional on-site liquid waste disposal. Undisturbed 60 cm long cores were subjected for approximately 120 days to constant ponding with simulated septic tank effluent, extended aeration effluent and distilled water. Column influents and effluents were monitored with respect to chemical oxygen demand (COD), biochemical oxygen demand (BOD), and solid residue fractions. Column influents differed markedly in COD and BOD content but column effluents had consistently low contents indicating the high renovative capacity of the soil. In situ tensiometric, redox, and flow rate measurements indicated development of the most severe barriers to flow in columns ponded with low BOD aerated effluent, followed closely by those ponded with high BOD septic tank effluent.

74:02G-047
COMPUTER MODELING OF NITROGEN TRANSFORMATIONS IN SOILS,
Mehran, M. and Tanji, K.K.
California University, Davis, Department of Water Science and Engineering,
Journal of Environmental Quality, Vol. 3, No. 4, p 391-395, October-December, 1974. 7 fig, 1 tab, 20 ref.

Descriptors: *Nitrification, *Dentrification, *Model studies, *Nitrogen, Computer models, Soil profiles, Soil investigations.

A nitrogen-transformation model was formulated for simultaneous computation of various N transformations: nitrification, denitrification, mineralization, immobilization, ion exchange, and plant uptake. These processes were assumed to obey first-order kinetics. Differential equations that describe the above processes are solved simultaneously by using the 4th-order Runge-Kutta method and the Adams-Bashforth-Moulton predictor-corrector equations. The computer model was tested against data reported from several incubation studies. This model could be linked to a transport model to predict the temporal and spatial distribution of various N species in soil profiles.

74:02G-048
A SIMULATION MODEL FOR PREDICTION OF HERBICIDE PERSISTENCE,
Walker, A.
National Vegetable Research Station, Wellesbourne, Warwick, England.
Journal of Environmental Quality, Vol. 3, No. 4, P 396-401, October-December, 1974. 5 fig, 1 tab, 10 ref.

Descriptors: *Simulation analysis, *Model studies, *Herbicides, Pollution, Computer model, Soil investigation, Meteorological data.

A simulation model for prediction of herbicide persistence in the field is described. The model combines the effects of soil temperature and soil moisture content on the rates of herbicide loss, determined experimentally under controlled conditions, with the fluctuations in surface soil temperature and moisture content in the field. The computer program includes methods of simulating surface soil temperatures and moisture contents from standard meteorological data. When data were used in the simulation model in conjunction with the relevant meteorological information, the patterns of loss of napropamide incorporated 2 to 3 cm in the field could be predicted. Napropamide was lost rapidly when applied to the soil surface, and since the model only takes into account losses through microbial or chemical metabolism, this could not be simulated. Some of the limitations and the potential benefit, of the simulation technique for prediction of pesticide persistence are discussed.

74:02G-049
NITRATE AND CHLORIDE LEACHING IN A SWELLING CLAY SOIL,
Kissel, D.E., Ritchie, J.T., and Burnett, E.
Texas A&M University, Temple, Texas Agricultural Experiment Station.

**Journal of Environmental Quality, Vol. 3, No. 4, p 401-404, October-December, 1974. 4 fig, 3 tab, 9 ref.**

**Descriptors: *Nitrates, *Chloride, *Leaching, *Nutrient removal, Soil investigations, Water quality, Lysimeter, Drainage water, Groundwater, Soil water movement.**

Leaching losses of applied NO(3)-N and Cl(-) from a swelling clay soil were measured using an undisturbed field drainage lysimeter. Nitrate-N and Cl(-), applied at 110 and 279 kg/ha, respectively, were detected in drainage water collected at a depth of 125 cm after the first large rainstorm. Applied fertilizer was leached when percolating rainwater carried the applied materials through large connected pores, bypassing other soil water inside soil structural units. Even though applied fertilizer began to be lost without the first rainstorm, concentrations of NO(3)-N and Cl(-) were not high until large amounts of water had drained below the root zone. Much more native soil nitrate was leached than soil nitrate concentrations in unfertilized plants would have indicated. The data indicate that leaching losses of nitrate from mineralization may be greater than those of applied nitrate when accumulated drainage is < 50 mm following fertilizer application.

74:02G-050
NITRATE OCCURRENCE IN SOME SOILS WITH AND WITHOUT NATRIC HORIZONS,
Gentzsch, E.P., Runge, E.C.A., and Peck, T.R.
Illinois University, Department of Agronomy.
Journal of Environmental Quality, Vol. 3, No. 1, p 89-94, January-March, 1974.
1 fig, 5 tab, 14 ref.

Descriptors: *Nitrates, *Nitrogen, *Soil properties, Soil investigations, Fertilization, Fertilizers, Groundwater, Water quality.

The effect of animal activity and fertilizer practices on the nitrate content in soils with and without natric horizons was investigated in a field study in southern Illinois where excessive groundwater nitrate levels were reported. Most of these soils are poorly drained. A comparison is provided by the poorly and well-drained soils without natric horizons observed in central Illinois. The results indicate that soils with natric horizons at shallow depths or dark-colored poorly drained soils had low levels of nitrate in the profile; all other soils showing increased nitrate levels in the entire profile or below the root zone were related to the amount of fertilizer used or the amount of animal activity. Animal operations resulted in larger amounts of nitrate in similar soil profiles than did fertilizer applications. Increased nitrate content of the groundwater, sampled in Washington County, similarly was related to fertilizer practices and animal activity in all soils, except under soils with natric horizons at shallow depths.

# Section VIII

# WATER CYCLE

## WATER IN PLANTS (Group 02I)

**74:02I-001**
**EVALUATION OF A THERMOCOUPLE HYGROMETER FOR MEASURING LEAF WATER POTENTIAL IN SITU,**
**Campbell, G.S. and Campbell, M.D.**
**Washington State University, Pullman, Department of Agronomy and Soils.**
**Agronomy Journal, Vol. 66, No. 1, p 24-27, January-February, 1974. 5 fig, 14 ref.**

**Descriptors: *Pressure measuring instruments, Pressure, Potato, Wheat, Vapor pressure**

Several methods for measuring leaf water potential in situ with thermocouple psychrometers or hygrometers have recently become available. Disadvantages of these methods include difficulty in construction or use, or excessive modification of the leaf environment. Comparisons between in situ and other measurements are generally lacking. We constructed an aluminum hygrometer which is relatively easy to build and use and covers only about 1.5 sq cm of leaf area. This hygrometer was tested in the laboratory and the field and readings were compared with those made with a pressure chamber for several plant species. The leaf hygrometer worked well in both field and laboratory situations. Comparisons between readings with the leaf hygrometer and a pressure chamber gave regression lines with slopes of 1, but the average pressure chamber reading was 0.4 to 1 bar lower than that obtained with the leaf hygrometer. The leaf hygrometer appeared to respond to plant water potential changes in less than 30 minutes. The equivalent error due to temperature gradients within the chamber was found to be less than 0.4 bar. Measurement precision with this technique appears to be about 1 bar or better.

74:02I-002
PINES ON A HIGH SALT DIET,
Belcher, C.R. and Gaffney, F.B.
Soil Conservation Service, Cape May Plant Materials Center, Cape May Court House, New Jersey.
Soil Conservation, Vol. 40, No. 2, p. 11, September 1974.

Descriptors: Salinity, Salt, Saline water, Saline soil, Pine trees.

It's enough to send chills down the back of any gardener, but Soil Conservation Service plant specialists in New Jersey are applying generous amounts of rock salt around pine seedlings.

74:02I-003
FIELD TEST OF A MODIFIED NUMERICAL MODEL FOR WATER UPTAKE BY ROOT SYSTEMS,
Feddes, R.A., Bresler, E. and Neuman, S.P.
Institute of Soils and Water, Volcani Center, Bet Dagan, Israel, Department of Soil Physics.
Water Resources Research, Vol. 10, No. 6, p 1199-1206, December 1974. 6 fig, 2 tab, 35 ref.
(See 74:02G-039)

74:02I-004
DIFFERING SENSITIVITY OF CORN AND SOYBEAN PHOTOSYNTHESIS AND TRANSPIRATION TO LEAD CONTAMINATION,
Bazzaz, F.A., Rolfe, G.L., and Windle, P.
Journal of Environmental Quality, Vol. 3, No. 2, p 156-158, April-June, 1974. 3 fig, 15 ref.
(See 74:05B-044)

# Section VIII

## WATER CYCLE

### EROSION AND SEDIMENTATION (Group 02J)

74:02J-001
RESERVOIR SEDIMENTATION,
McHenry, J.R.
Agricultural Research Service, Oxford, Mississippi, Sedimentation Laboratory.
Water Resources Bulletin, Vol. 10, No. 2, p 329-337, April 1974. 1 fig, 2 tab, 18 ref.

Descriptors: *Reservoir silting, *Sedimentation, Erosion, Sediment control, Sediment yield, Desilting, Reservoir design, Reservoir operation, Water management(Applied), Sedimentation rates.

Reservoirs, as well as lakes and estuaries, are subject to sediment accumulation. The rate at which sedimentation occurs is accelerated or diminished by man's activities. Acceptable rates of sedimentation may be determined on the basis of costs of sediment storage and removal. A review of reservoirs constructed with sediment removal capabilities is given. The rates of reservoir sedimentation in the United States are summarized based on reliable data obtained from all sizes of reservoirs. Problems confronting the engineer concerning reservoir construction and maintenance are discussed on the basis of these data.

74:02J-002
SEDIMENT ROUTING IN IRRIGATION CANAL SYSTEMS,
Mahmood, K.
Colorado State University, Fort Collins, Department of Civil Engineering.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 100, No. IR1, Paper 10401, p 49-67, March 1974. 8 fig, 3 tab, 12 ref, append.

Descriptors: *Sediment transport, *Irrigation water, Routing, Sedimentation, Canals, Sediment control, Simulation analysis, Numerical analysis, Bed load.

The routing of bed material load through a branching irrigation canal system may be calculated in such a way as to insure sediment discharge equilibrium. All the sediment entering the system is disposed of with the water. The system equilibrium can be more easily achieved if smaller sediment concentrations are allocated to irrigation diversions from smaller channels. An approximate numerical model predicts the bed material load from farm turnouts.

74:02J-003
CONCEPTS OF MATHEMATICAL MODELING OF SEDIMENT YIELD,
Bennett, J.P.
Geological Survey, Bay Saint Louis, Mississippi.
Water Resources Research, Vol. 10, No. 3, p 485-492, June 1974. 1 fig, 34 ref.

Descriptors: *Sediment yield, *Mathematical models, Reviews, Equations, *Erosion, Soil erosion, Sediment transport, Slopes.

A deterministic structure imitating a sediment yield model should mathematically approximate the behavior of two distinct phases of the phenomenon, the upland phase and the lowland channel phase. For upland erosion, research is most needed to explain the influence of meanders on bed material transport and to develop a floodplain accounting component. In both phases, research is needed to explain the effects of unsteadiness and flow nonuniformities on transport. Sensitivity analysis studies of sediment yield models are needed to illustrate how well the models can be calibrated and what output precision can be expected from input data with known statistical characteristics. Present estimates indicate that although a regression of annual sediment discharge on annual water discharge might be expected to give a prediction within 20% of the observed value, even a well-calibrated digital model might give an error greater than 40% for a single storm on a small watershed.

74:02J-004
TOTAL SEDIMENT DISCHARGE SAMPLING OVER SILLS,
Hansen, E.A.
Forest Service (United States Department of Agriculture), Cadillac, Michigan. North Central Forest Experiment Station.
Water Resources Research, Vol. 10, No. 5, p 989-994, October 1974. 5 fig, 2 tab, 8 ref.

Descriptors: *Sediment discharge, *Sampling, *Bed load, *Sands, Roughness (Hydraulic), Turbulence, Streams, Sediment load, Bed load samplers, Measurement, Discharge measurement, On-site data collections, Channels, Currents(Water).

Described were (1) the method of installation of wooden sills on the bed of streams, (2) collection of bed load sediment data at the sills, (3) analysis of the bed load sediment data, and (4) comparison of these results with bed load sediment data collected at stream beds where sills were not installed. It was indicated that wooden sills permit collection of bed load sediment normally missed in the unsampled zone. The advantages associated with bed load data collected at sills were; (1) sills provide a rigid unchanging control at which to sample, (2) they reduce the chance of sample bias from sediment stirred up by the wader, and (3) they permit control of the sampling interval because the sample points can be marked directly on the sills. Analysis of the field data indicated that in all probability the 'sill samples' provided better measurements of total sediment discharge than the traditional stream samples. The nonuniformity of bed load discharge in the stream cross-section complicated the problem of obtaining an unbiased sample of the total sediment discharge.

74:02J-005
REGIONAL SEDIMENT YIELD ANALYSIS OF ALASKA STREAMS,
Guymon, G.L.
Alaska University, College. Institution of Water Resources. Journal of the Hydraulics Division, American Society of Civil Engineers, Vol 100, No HY1, Paper 10255, p 41-51, January 1974. 3 fig, 2 tab, 4 ref, append.

Descriptors: *Sediment yield, *Alaska, *Sediment load, Equations, *Regression analysis, Sedimentation, Suspended load, Statistical methods, Sampling, *Glaciohydrology.

Sparse suspended sediment data for Alaska were evaluated to verify regional sediment yield relationships and to test alternative regression correlations using readily obtained watershed parameters. Glacier-fed streams in the south-central region of Alaska were emphasized, although one nonglacial stream in the interior region of Alaska was included for comparison. Plausible, simple relationships can be developed for stream reaches well downstream from the glacier which delivers a high fraction of the total suspended sediment load. A great deal of uncertainty is associated with correlation attempts for short stream reaches near the glacier delivery source.

74:02J-006
EVALUATION IRRIGULAR SLOPES FOR SOIL LOSS PREDICTION,
Foster, G.R. and Wischmeier, W.H.
Purdue University, Lafayette, Indiana.
Transactions of the American Society of Agricultural Engineers, Vol. 17, No. 2,
p 305-309, March-April 1974. 3 fig, 8 ref.

Descriptors: *Soil erosion, Soil management, Soil conservation, Erosion, Slope stability, Topography, Evaluation, Agriculture, Construction.

The effects of slope irregularities on soil erosion by water were analyzed on the basis of recent progress in mathematical simulation of the basic erosion processes. This report presents the analysis and extends it to routine field application. A technique is proposed for evaluating the universal soil-loss equation's topographic factor, LS, for irregular field or construction-site slopes. The technique also provides a means of evaluating the effects of differences in soil erodibility that may be associated with changes in slope steepness. It does not, however, predict deposition that may occur on a slope. Irregular slopes are not accurately evaluated by using average values for slope steepness and soil erodibility in combination with overall length, and additional very helpful detail can be readily obtained. The proposed technique has direct application value both on farmland and on construction sites.

74:02J-007
EXPERIMENTAL STUDY OF RILL EROSION,
Mosley, M.P.
Colorado State University, Fort Collins, Geology Department.
Transactions of the American Society of Agricultural Engineers, Vol. 17, No.5,
p 909-913 & 916, September-October 1974. 7 fig, 2 tab, 20 ref.

Descriptors: *Erosion rates, *Rill erosion, Surface runoff, Surface water, Sediment yield, Sediment transport, Sheet erosion.

An experimintal study of soil erosion on unvegetated soil surfaces has shown that a number of types of erosion may occur. These are, in approximate order of importance, erosion by overland flow, microrilling, rainsplash, rill cutting, and lateral planation by rills. Observation and simple statistical analysis suggested that rilling was predominant; it was responsible for both detachment of soil particles as the rill channels were incised, and for the transport of particles detached by other processes, such as rainsplash. For rills which had reached an "equilibrium" stage of development, sediment yields were positively related to surface slope and length, as previous research has shown to be the case for sheet erosion in general. However, sediment yields were also related to total rill channel length and drainage density; it appears that rilling deserves more attention than it has hitherto received.

74:02J-008
SEDIMENT YIELD FROM SOUTHWEST IDAHO RANGELAND WATERSHEDS,
Johnson, C.W., Stephenson, G.R., Hanson, C.L., Engleman, R.L., and Englebert, C.D.
United States Department of Agriculture, Agricultural Research Service, Boise,
Idaho, Northwest Watershed Research Center.
Presented at 1974 Winter Meeting of the American Society of Agricultural
Engineers, December 10-13, 1974. Chicago, Illinois. 6 fig, 7 tab, 15 ref.

Descriptors: *Sediment yield, Idaho, Watersheds (Basins), Watershed management, Runoff, Stream erosion.

Information collected shows that a small percentage of yearly runoff produces most of the yearly sediment and that major floods occur during the winter.

**Contrary to what is normally observed, sediment concentrations and yearly sediment yield increased with watershed size. Stream bank erosion seemed to be the main source of sediment on the largest watersheds and "channel flushing" caused high sediment concentrations.**

74:02J-009
INFLUENCES OF MULCH RATE AND SLOPE STEEPNESS ON INTERRILL EROSION,
Lattanzi, A.R., Meyer, L.D., and Baumgardner, M.F.
Purdue University, West Lafayette, Indiana.
Soil Science Society of America Proceedings, Vol, 38, No. 6, p 946-950,
November-December, 1974. 4 fig, 4 tab, 14 ref.

Descriptors: *Erosion, *Erosion control, *Erosion rates, Infiltration, Runoff, Soil conservation, Sediment yield, Simulated rainfall, Mulching, Slope protection, Slope stabilization.

Soil and water losses from plots representing field areas between rills were studied for four rates of straw mulch at four slope steepnesses. Three simulated rainstorms totaling 2 hours at 6.4 cm/hour were applied to a 61- by 61-cm test area of Russell silt loam soil. Interrill erosion was reduced about 40% by mulch applied at a rate of only 0.5 metric tons/ha and about 80% by 2 tons/ha, as compared with no mulch. Erosion was negligible at the 8 tons/ha rate. Soil losses from the interrill areas at 20% slope were only about double those measured at 2% slope, whereas widely used erosion equations show that total field erosion would increase about 20-fold over this range of steepnesses. Water loss by runoff was independent of slope steepness, but it was slightly reduced by mulch at a rate of 2 tons/ha and was greatly reduced by the 8 tons/ha rate. After 40 minutes of rainfall, sealing of the soil surface by raindrop impact had reduced infiltration rates for treatments with 0 to 2 tons/ha of mulch to only 20% of those with 8 tons/ha.

74:02J-010
SEDIMENT IN IRRIGATION AND DRAINAGE WATERS AND SEDIMENT INPUTS AND OUTPUTS FOR TWO LARGE TRACTS IN SOUTHERN IDAHO,
Brown, M.J., Carter, D.L., Bondurant, J.A.
Snake River Conservation Research Center, Kimberly, Idaho.
Journal of Environmental Quality, Vol. 3, No. 4, p 347-351, October-December,
1974. 1 fig, 3 tab, 10 ref.

Descriptors: *Sediment discharge, *Sediment control, *Sediment yield, *Sedimentation, Runoff, Return flow, Water quality, Water quality control.

Sediment inputs from Snake River irrigation water and sediment losses back to the river were measured for two large irrigated tracts in southern Idaho. There was a net sediment accumulation of 0.69 metric tons/ha onto the 65,000 ha Northside tract but a net sediment loss of 0.46 metric tons/ha from the 82,000 ha Twin Falls tract. Differences in sediment losses from the two tracts result from the difference in sedimentation in the drain-ways of the two projects. Sediment deposited in drains on the Northside tract amounted to 4.5 metric tons/ha compared to 0.95 metric tons/ha for the Twin Falls tract. Erosion loss from farms could be reduced within each tract by more careful use of water and construction of on-farm sediment retention ponds. This would also reduce the amount of sediment returned to the river and lower costs of mechanically removing sediment from drains and canals. Construction of sediment retention ponds along main drains and reducing the amount of surface runoff returning to the river would also reduce the amount of sediment returning.

# Section IX

## WATER CYCLE

### CHEMICAL PROCESSES (Group 02K)

74:02K-001
**THE INFLUENCE OF GEOLOGICAL MEMBRANES ON THE GEOCHEMISTRY OF SUBSURFACE WATERS FROM MIOCENE SEDIMENTS AT KETTLEMAN NORTH DOME IN CALIFORNIA,**
Kharaka, Y.K. and Berry, F.A.F.
California University, Berkeley, Department of Geology and Geophysics.
Water Resources Research, Vol. 10, No. 2, p 313-327, April 1974. 11 fig, 3 tab, 40 ref.

Descriptors: *Water chemistry, *Oil fields, *Membrane processes, Geochemistry, California, Water temperature, Sodium, Ammonia, Magnesium, Calcium, Strontium, Chlorides, Sulfates, Iodine, Bromine, Silica, Ion exchange, Clays, Zeolites, Shales.

In the Kettleman North Dome oilfield in California, the waters from the Temblor formation (Miocene) are principally meteoric in origin, related to recharge areas located to the west. Their chemistry relative to meteoric water is attributed to hyperfiltration through geological membranes as well as to water-rock interactions. The chemistry of the waters in each subzone of the Temblor formation is characteristic of that subzone and shows membrane effluent characteristics to a given subzone with respect to the one stratigraphically below it. The chemical relations are attributed to increased efficiency of shale membranes with increased depth of burial. Membrane behavior of shales controls completely or in part the distribution of the following ratios: Li/Na, Rb/Na, $NH_3$/Na, Mg/Ca, Sr/Ca, Ca/Na, alkalinity/Cl, $SO_4$/Cl, I/Br, and B/Cl. Some of these ratios are modified by temperature-controlled water-rock interactions. The K/Na ratios and the $SiO_2$ and Ba concentrations are completely dependent on water-rock interactions.

# Section X

## WATER SUPPLY AUGMENTATION AND CONSERVATION

### WATER YIELD IMPROVEMENT (Group 03B)

74:03B-001
SEEPAGE LOSSES FROM IRRIGATION CANALS,
Horcher, F. and Szigyarto, Z.
International Commission on Irrigation and Drainage, p 63-70, January 1974.
2 fig, 2 tab, 16 ref.

Descriptors: *Seepage, *Irrigation canals, Irrigation effects, Water loss, Water conveyance, Water consumption.

Since the setting up of the Trans-Tisza District Water Authority in 1963, systematic studies have been made by the Research Institute for Water Resources Development in the irrigation system of the Deletı (Eastern) irrigation main canal or precisely speaking, in the irrigation section K.IV of this system to develop both the design principles and operation regulations of irrigation canal systems. In this paper the results of the previous experimental series are summarized, and studies carried out between 1967 and 1971 on the determination of seepage losses in the main canal of the irrigation section K.IV are described.

# Section XI

## WATER SUPPLY AUGMENTATION AND CONSERVATION

## USE OF WATER OF IMPAIRED QUALITY (Group 03C)

74:03C-001
EFFECTS OF COLORADO RIVER WATER QUALITY AND SUPPLY ON IRRIGATED AGRICULTURE,
Moore, C.V., Snyder, H.H. and Sun, P.
Economic Research Service, Davis, California.
Water Resources Research, Vol. 10, No. 2, p 137-144, April 1974. 7 fig, 2 tab, 4 equ, 8 ref.

Descriptors: *Irrigation water, *Water supply, *Saline water, *Water quality, Agriculture, Estimating, Linear programming, Regional analysis, Water demand, Irrigated land, Optimization, Colorado River, Farms, Size, Soils, Prices, Water rates, Mathematical models, Systems analysis, *California.

Considered are salination effects upon irrigation water supplies in the Imperial Valley of California. A production function relating irrigated crop yield to the quality and supply of irrigation water is developed. The objective function is to maximize the return to land and water. Described is a linear programming, farm model constructed to estimate the probable effects of various levels of supply and quality. A regional programming model, an aggregation of three different size individual farms, reflects the distribution of soils and the cost structure representative of farm size. Given the production function, cropping pattern and irrigation management can be optimized using the linear programming models. Use of the regional model for estimating the demand schedule for irrigation water is discussed. Results show that the adverse effects of saline irrigation water can be offset by applying additional water over and above that required for plant transpiration. A degradation of the water supply in the Colorado River at Imperial Dam from the existing level of electroconductivity to the projected level for the year 2000 would cause a decline in the return to land and water of about 14%. Because of the relatively elastic demand for irrigation water at the current price, any attempt to ration water through a market price mechanism would have no effect, unless water rates were about double their current levels.

74:03C-002
AUSTRALIAN VINEYARD USES SEWAGE EFFLUENT WITH TRICKLE IRRIGATION,
Read, A.L., Pietsch, M.F. and Matheson, W.E.
Kinnaird Hill deRohan and Young, Ltd. Norwood, South Australia.
Proceedings of the Second International Drip Irrigation Congress, pp. 382-387, July 1974.

Descriptors: *Effluents, *Sewage, *Sewage disposal, *Sewage effluents, *Vine crops, Irrigation, Irrigation systems, Irrigation practices, Agriculture, Clogging.

The Angle Vale Vineyard is located 32 kilometres north of Adelaide, South Australia. Supplementary irrigation is necessary for the growth of vines in the area. In 1970, Government legislation precluded the future use of water in the area, and a decision was made to use sewage effluent from Adelaide which was the only supplementary irrigation available. The 40 hectare vineyard had trickle irrigation installed and has since been enlarged to 180 hectares. The effluent has a T.D.S. varying from 1,300 to 1,800 mg/l and a varying but high algal content. The paper describes the problems of filtration and growths within the pipelines and how these problems were overcome. Monitoring of soil conditions has been necessary to study the changes in soil salinity. Maximum salinities have occurred at the perimeter of the wetted zone, approximately 50 cms from the vine rows. Total soluble salts have increased from 0.035% in the centre of the vine rows to 0.086-0.109% at the perimeter of the wetted zones. Analyses of the vine leaves and wine made from the first vintage are also reported.

74:03C-003
SALT TOLERANCE OF MEXICAN WHEAT: II. RELATION TO VARIABLE SODIUM CHLORIDE AND LENGTH OF GROWING SEASON,
Bernal, C.T., Bingham, F.T., and Oertli, J.
California University, Riverside, Department of Soil Science and Agricultural Engineering.
Soil Science Society of America Proceedings, Vol. 38, No. 5, p 777-779, September-October, 1974. 7 fig, 2 tab, 15 ref.
(See 74:03F-133)

74:03C-004
SURFACE PLUGGING DURING BASIN RECHARGE OF TURBID WATER,
Jones, O.R., Goss, D.W., and Schneider, A.D.
United States Department of Agriculture, Southwestern Great Plains Research Center, Bushland, Texas.
Transactions of the ASAE, Vol. 17, No. 6, p 1011-1014 & 1019, November-December 1974. 7 fig, 2 tab, 9 ref.
(See 74:03F-149)

74:03C-005
GROWTH RESPONSE OF CROPS TO DEPTH AND SALINITY OF GROUNDWATER AND SOIL SUBMERGENCE. I. WHEAT (TRITICUM AESTIVUM L.)
Chaudhary, T.N., Bhatnagar, V.K. and Prihar, S.S.
Punjab Agricultural University, Ludhiana, India, Department of Soils.
Agronomy Journal, Vol. 66, No. 1, p 32-35, January-February, 1974. 3 fig, 4 tab, 10 ref.

Descriptors: Salinity, Saline soil, Saline water, Crop response, Crop production, Groundwater, Lysimeters.

Information on crop response to depth and salinity of groundwater and soil submergence is important for planning drainage and optimizing crop production. Response of a semidwarf wheat to four depths (60, 90, 120, and 150 cm) and three salinities (EC 0.5, 2.9, and 5.2 mmho/cm) of groundwater was studied in lysimeters filled with silt loam soil during 1970-71 and 1971-72. The plants were irrigated with water of EC 0.5 mmho/cm when the lysimeters with a 150-cm water table depth indicated a tension of 0.5 bar at a 75-cm depth. Groundwater of EC 0.5 mmho/cm at 60 and 90-cm depths gave highest yields. Comparable increase in the salinity of groundwater caused greater reduction in yield with shallow water tables than with deep water tables. It is indicated that critical depth of groundwater, for optimum crop production, would vary in relation to its salinity.

## Section XII

## WATER SUPPLY AUGMENTATION AND CONSERVATION

### CONSERVATION IN AGRICULTURE (Group 03F)

74:03F-001
FUNCTIONS TO PREDICT OPTIMAL IRRIGATION PROGRAMS,
Stewart, J.I., Hagan, R.M. and Pruitt, W.O.
California University, Davis, Department of Water Science and Engineering.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 100, No. IR2, Paper No. 10626, p 179-199, June 1974. 5 fig, 5 tab, 36 ref.

Descriptors: *Irrigation programs, *Irrigation efficiency, *Optimum devesedment plans, Evapotranspiration, *Droughts, Scheduling, Soil water, Vegetation, Seasonal, Corn(Field), Research, Measurement, Systems analysis.

Maximum water-use efficiency often occurs at irrigation levels still lower than the maximum profit point. A methodology is presented for prediction of optimal irrigation programs at any given level of irrigation water supply. The prediction is based on analysis of: (1) Davis, California research findings concerning growth characteristics of the crop which influence maximum yield, evapotranspiration (ET) requirement, soil water uptake, and response to ET deficits; and (2) measurements of climate, soil, and irrigation system performance which influence the requirement for ET to be supplied from irrigation, and the percentage of irrigation water evapotranspired. An optimal program maximizes profit or water-use efficiency. Programming dates and depths of irrigations are based on comparison of the estimated sequence of maximum ET rates throughout the season with the sequence of actual ET rates expected if no irrigation is given. The difference constitutes an expected sequence of ET deficits which carefully programmed irrigations may alleviate fully or in part. Time relationships of corn leaf canopy and root system development researched at Davis are combined with irrigation planning site measurements of climate, soil, and soil water content to estimate the sequence of ET deficits. Measurement of actual irrigation operational efficiency completes the needed information.

74:03F-002
TOWARD THE STRUCTURE OF A PRODUCTION FUNCTION FOR WHEAT YIELDS WITH DATED INPUTS OF IRRIGATION WATER,
Minhas, B.S., Parikh, K.S. and Srinivasan, T.N.
Indian Statistical Institute, New Delhi, Planning Unit.
Water Resources Research, Vol. 10, No. 3, p 383-393, June 1974. 6 fig, 4 tab, 16 equ, 27 ref.

Descriptors: *Irrigation water, *Irrigation efficiency, Water utilization, *Crop response, *Soil moisture, Analytical techniques, *Wheat, *Alfalfa, Estimating, Yield equations, Ohio, Optimization, Time, Methodology, Evapotranspiration, Water quantity, Plant growth, Water allocation(Policy), Systems analysis.

To date, the interdependence between the rate of water used by plants and the available stocks of moisture in the soil, the temporal interdependence between water use at different time points, and the consequences of these interdependencies for the relationship between time profiles (as well as quantities) of water used by crop plants and yields generally have not been analyzed in a unified framework. Presented is one such framework for the analysis of optimal use of irrigation water. The mathematical form of a water use function, estimated from experimental data, has been used to compute the time profiles of actual water use for wheat in Delhi (India) and alfalfa in Ohio. The estimated time profiles of consumptive use have been used to determine the relationship between wheat yields and dated inputs of water in Delhi.

74:03F-003
DATING TERMINATION OF COTTON IRRIGATION FROM SOIL WATER-RETENTION CHARACTERISTICS,
Grimes, D.W. and Dickens, W.L.
California University, Davis, Department of Water Science and Engineering.
Agronomy Journal, Vol. 66, No. 3, p 403-404. 1974 Illus.

In the semiarid San Joaquin Valley of California (USA), about 90% of the evapotranspiration needs for nonstressed cotton (Gossypium hirsutum L.) are met by irrigation. Soil water-retention characteristics determine the frequency with which irrigations must be made to replenish depleted soil water during the growing season. Studies were conducted in the San Joaquin Valley, on 2 soils that have a broad difference in water retention ability, to determine the best irrigation termination date for cotton. A multiple-regression model that included time of irrigation termination and water retention capacity of soil as independent variables was used to describe the influence of these variables on cotton production potential (R2=0.71). Prepared from the function was a graphic relation illustrating an irrigation termination time that allows a 98% relative yield on the basis of the amount of available water the soil can retain. An optimum irrigation termination time was 28 days later for the low water-retaining soil of the study than for the high water-retaining soil. Correct timing of a final irrigation saved water and hastened the opening of mature bolls without harm to lint yield or quality.

74:03F-004
COMPARISON OF DRAINAGE METHODS IN A HEAVY-TEXTURED SOIL,
Schwab, G.O., Fausey, N.R. and Michener, D.W.
Ohio Agricultural Research and Development Center, Wooster.
Paper No. 72-727 presented at Winter Meeting of the American Society of Agricultural Engineers, December 11-15, 1972, Chicago, Illinois. 5 p, 1 tab, 6 ref.

Descriptors: *Drainage, Surface drainage, Subsurface drainage, Tile drainage, Crop response, Soil water, Drainage engineering, Soil water movement.

Corn, oat, and soybean yields from surface drained, tile drained, and a combination of tiled and surface drained plots in northern Ohio were obtained over a 10-year period. Both conventional tillage and no tillage practices were included. Rainfall plus irrigation and drainage flow effects on yields were studied by linear regression techniques.

74:03F-005
INFILTRATION AND ROOT EXTRACTION FROM SUBSURFACE IRRIGATION LATERALS,
Gilley, J.R. and Allred, E.R.
Minnesota University, St. Paul, Department of Agricultural Engineering.
Paper No. 72-743 presented at Winter Meeting of the American Society of Agricultural Engineers, December 11-15, 1972, Chicago, Illinois. 27 p, 11 fig, 4 tab, 29 ref.

Descriptors: *Irrigation, *Subsurface irrigation, Irrigation practices, Soil moisture, Soil water movement, Soil physics, *Infiltration, Model studies.

An analytical solution to the soil moisture flow equation was used to simulate flow in partially saturated soils during steady infiltration from buried line sources. A series of plane sinks was used to model water consumption by plants. The resulting model was used to determine optimum lateral placement to obtain desired crop extraction patterns.

74:03F-006
PROCEEDINGS OF THE SECOND INTERNATIONAL DRIP IRRIGATION CONGRESS,
Second International Drip Irrigation Congress,
California University and United States Department of Agriculture, Agriculture Research Service.
Second International Drip Irrigation Congress, July 7-14, 1974, San Diego, California.

Descriptors: Crop response, Design, Design criteria, Design flow, Economics, Evaporation pans, Fertilization, Furrow irrigation, Hydraulic properties, Infiltration, Irrigation effects, Irrigation efficiency, Irrigation practices, Irrigation water, Mathematical models, Orifice flow, Orchards, Return flow, Root development, Salinity, Soil water movement, Subsurface irrigation.

Research related to trickle irrigation (drip irrigation) is being conducted throughout the United States and in many other countries of the world. The 101 papers presented discuss topics such as design methods, hydraulics, crop response, salinity, water filtration, fertilization, irrigation scheduling, emitter design, emitter clogging, wetting patterns, and much more as related to this relatively new irrigation method.

74:03F-007
PERFORMANCE OF PLANTS WITH DRIP IRRIGATION,
Aljibury, F.K., Gerdts, M., Lange, A., Huntamer, J. and Leavitt, G.
San Joaquin Valley Agricultural Research and Extension Center, Parlier, California.
Proceedings of the Second International Drip Irrigation Congress, pp. 497-502, July 1974. 2 fig, 3 tab, 3 ref.

Descriptors: *Oranges, *Water utilization, *Crop response, Penetration, Furrow irrigation, Crop production, Irrigation practices, Irrigation, Agriculture.

Experiments were established to study the effect of drip irrigation on water use efficiency and production in oranges and to study the effect of drip and furrow irrigation on water penetration and performance of plums. Orange production records show higher production with drip irrigation which is attributed to improved water penetration. Plum production records show no significant difference in production or fruit quality, but irrigation efficiency was improved.

74:03F-008
THE RELATION BETWEEN DRIP IRRIGATION, PHYTOPHTHORA ROOT ROT OF AVOCADO, AND FUNGICIDES,
Zentmyer, G.A., Guillement, F.B. and Johnson, E.L.V.
California University, Riverside, California.
Proceedings of the Second International Drip Irrigation Congress, pp. 512-514, July 1974.

Descriptors: *Diseases, *Disease resistance, *Fungicides, Irrigation practices, Irrigation systems, Irrigation, Agriculture.

Studies have been initiated to determine the effect of drip irrigation on development, spread and control of Phytophthora root rot of avocado caused by Phytophthora cinnamomi. In one test in naturally infested soil, development of Phytophthora root rot of avocado seedlings was considerably slower under drip than under sprinkler irrigation. There were also indications of less rapid spread of the fungus from infested into noninfested soil under the drip, as compared with the sprinkler regime. At the end of the first year of the experiment, 6 of 12 seedlings were still healthy in soil infested with P. cinnamomi when irrigated with a drip system, compared with 2 healthy seedlings of 12 irrigated with spitters. A number of soil fungicides have been tested in the greenhouse for possible use in drip systems, by applying frequent applications (every other day or every fourth day) to avocado seedlings growing in soil infested with Phytophthora cinnamomi. The best control of the disease has been obtained with ethazol (5-ethoxy-3-trichloremethyl-1, 2, 4-thiadiazole) chemicals for incorporation in drip systems is still in the early stages. One field plot has been established with Terrazole applied in a drip system to 10-year old avocado trees infected with Phytophthora root rot, and also to young trees replanted in infested soil.

74:03F-009
WATER USE WITH DRIP IRRIGATION,
Aljibury, F.K., Marsh, A.W. and Huntamer, J.
San Joaquin Valley, Agricultural Research and Extension Center, Parlier, California.
Proceedings of the Second International Drip Irrigation Congress, pp. 341-345, July 1974.

Descriptors: *Evaporation pans, *Water requirements, Irrigation practices, Irrigation water, Irrigation system, Irrigation design, Frequency.

In the absence of proper equations to calculate water requirements with drip irrigation, irrigation consultants and dealers in California have used the same water use data developed for conventional irrigation systems. Since one of the primary advantages of drip irrigation is water savings, development of water budget to fit drip irrigation became necessary. To accomplish this objective, several drip irrigation studies were initiated in the San Joaquin Valley of California. These studies were conducted on farms where citrus, avocados, plums, olives, and grapes were grown. Applied water was measured using flow meters while the frequency and amount of water application was determined with tensiometers which were set to switch the water on at 30 centibars. Water evaporation from Class A pans established in large alfalfa fields was recorded regularly. A table is presented showing suggested drip water application as a function of Class A pan evaporation and percent plant coverage.

74:03F-010
DRIP IRRIGATION ON CITRUS,
Bester, D.H., Lotter, D.C. and Veldman, G.H.
Zebediela Estates, Republic of South Africa.
Proceedings of the Second International Drip Irrigation Congress, pp. 58-64, July 1974. 2 fig, 1 tab.

Descriptors: *Evaporation pans, Irrigation, Agriculture, Sprinkler irrigation, Wetting, Fertilization, Filtration, Orchards, Citrus fruits.

A comparative study was conducted on citrus to establish the comparative efficiency of drip irrigation, dragline sprinkler irrigation, and a hose system discharging water directly into irrigation basins in South Africa. The following aspects of drip irrigation were investigated: 1) Soil moisture determinations and wetting patterns, 2) the possibility of using an evaporation pan to determine irrigation requirements, 3) the effect of different numbers and spacing of drippers per tree, 4) the effect of different dripper discharge rates, 5) practicability of using microtubes as drippers, 6) the possibility of applying fertilizers through a drip irrigation network, and 7) factors affecting the distribution efficiency of a drip irrigation system.

74:03F-011
CHANGE IN ROOT DISTRIBUTION OF MATURE PEAR TREES IN RESPONSE TO TRICKLE IRRIGATION,
Black, J.D.F. and Mitchell, P.O.
Victorian Department of Agriculture, Ferntree Gully, Australia.
Proceedings of the Second International Drip Irrigation Congress, pp. 437-438, July 1974.

Work reported was designed to obtain an idea of the rate of adaption of the root distribution of pear trees grown under uniform sprinkler irrigation for 18 years and then converted to trickle irrigation for two years with one emitter per tree. Flow rate per emitter was 8 ℓ per hour per tree. After two seasons the entire root system of 4 trees was exposed and examined for changes in response to the continuously moist but restricted wetted soil volume in the root zone. The intensity of new root growth was markedly higher inside the wetted soil volume.

74:03F-012
WATER UPTAKE BY AN APPLE TREE WITH VARIOUS PROPORTIONS OF THE ROOT SYSTEM SUPPLIED WITH WATER,
Black, J.D.F. and West, D.W.
Victorian Department of Agriculture, Ferntree Gully, Australia.
Proceedings of the Second International Drip Irrigation Congress, pp. 432-433, July 1974. 1 fig, 1 tab.

Descriptors: *Apple, *Root development, Irrigation, Agriculture.

Water uptake by young apple trees with 1/4, 1/2, and 3/4 of their root systems supplied with water was related to the uptake with the total system supplied with water in a split root pot trial. The respective percentages of water uptake compared with the totally watered system were 74, 88, and 94 percent.

74:03F-013
MONITORING SOIL SALINITY AND LEAF NUTRIENT LEVELS IN A YOUNG AVOCADO ORCHARD UNDER DRIP IRRIGATION,
Branson, R.L., Gustafson, C.D., Marsh, A.W., Davis, S. and Strohman, R.A.
California University, Riverside, California.
Proceedings of the Second International Drip Irrigation Congress, pp. 364-367, July 1974. 2 tab, 5 ref.

Descriptors: *Salinity, *Monitoring, *Orchards, *Leaching, *Nutrients, Irrigation, Agriculture.

Salinity control is an important part of the management program for avocado production because of this crop's low tolerance to salts. Soil salinity in the root zone of a newly planted avocado orchard was monitored for four years. The orchard, located in a semi-arid region of southern California, is irrigated with a moderately saline water from the Colorado River. Soil salinity rose to marginal levels during each irrigation season under both irrigation methods. Winter rainfall, however, leached accumulated salts from the soil each year. Distribution of the rainfall, as well as total amount, was an important factor with regard to adequacy of leaching. Leaf samples were analyzed annually to obtain information on the uptake of chloride, an ion toxic to avocado at relatively low levels. Leaf analysis data are also being used to evaluate the fertilization program.

74:03F-014
TRICKLE IRRIGATION MANAGEMENT FOR COTTON AND CABBAGE,
Bucks, D.A., Erie, L.J. and French, O.F.
United States Water Conservation Laboratory, Phoenix, Arizona.
Proceedings of the Second International Drip Irrigation Congress, pp. 351-356, July 1974. 5 fig, 4 ref.

Descriptors: *Cotton, *Frequency, *Consumptive use, *Water utilization, Agriculture, Irrigation, Furrow irrigation, Comparative productivity, Crop response.

Cotton and cabbage studies were initiated to evaluate the effects on crop production of specified quantities and frequencies of water applications using trickle irrigation. Different quantities of irrigation water were applied at frequencies of 3, 6, and 12 days. Both studies were conducted on small plots of fine-textured, clay-loam soil, using a moderately saline water. Results of these studies indicate the following: (1) the amount of soil moisture needed by the cotton and cabbage plants for high production was approximately the same as the presently-accepted consumptive use; (2) increasing frequency of trickle to 3 days did not increase yields on this soil; and (3) trickle irrigation can decrease irrigation water requirements under conditions where furrow-irrigation would not attain a high overall irrigation efficiency.

74:03F-015
TRICKLE IRRIGATION MANAGEMENT FOR GRAPES,
Bucks, D.A., Erie, L.J., Nakavama, F.S. and French, O.F.
United States Water Conservation Laboratory, Phoenix, Arizona.
Proceedings of the Second International Drip Irrigation Congress, pp. 503-507,
July 1974. 3 fig, 1 tab, 3 ref.

Descriptors: *Crop response, Agriculture, Irrigation, Consumptive use, Furrow irrigation, Frequency, Water utilization, Irrigation design, Irrigation practices, Water requirements.

A three-year field investigation is being conducted to determine irrigation management and design requirements for grape production. Trickle irrigation treatments include three irrigation quantities, based on ratios of a consumptive-use estimate; three irrigation frequencies--daily, 3-day and 6-day; and a variation of one or two trickle irrigation emitters per vine. Furrow irrigation treatments include the same three seasonal quantities used for the trickle irrigation applied in two or three furrows per vine; however, the irrigation frequency is varied, based on the consumptive use. First-year results were as follows: there was a 13 percent increase in yield for trickle irrigation with two emitters per vine over furrow irrigation; a 9 percent greater yield for two emitters over one emitter per vine; a 6 percent increase in berry size for trickle-irrigated fruit over furrow-irrigated; little difference in sugar content between irrigation treatments; and little difference in yield between trickle irrigation frequencies.

74:03F-016
RESPONSE OF MATURE CITRUS TRESS ON DEEP SANDY SOIL TO DRIP IRRIGATION,
Cole, P.J. and Till, M.R.
South Australian Department of Agriculture, Adelaide, Australia.
Proceedings of the Second International Drip Irrigation Congress, pp. 521-526,
July 1974. 1 fig, 4 tab, 1 ref.

Descriptors: *Oranges, *Crop response, Agriculture, Irrigation, Management orchards, Salinity, Irrigation design, Irrigation practices, Irrigation systems.

A demonstration trial on mature vallencia oranges was established to provide guidelines for future drip irrigation management in Australia. The trees are on a deep sandy soil and were established and previously maintained by sprinkler irrigation. There may be up to 450 mg/l total dissolved salts in the irrigation water. Two designs of drip irrigation have been used - one with a row of drippers along the base of the trees only, and the other with a line along both the base and in midrow. There are twice the number of drippers in this latter system, each of half the flow rate of the former. A difference in performance of trees are yielding less than sprinkler irrigated trees, with double line drip irrigation better than single line drip irrigation.

74:03F-017
INFLUENCE OF DIFFERENT AMOUNTS OF IRRIGATION--WATER, IRRIGATION--INTERVALS AND FERTILIZERS ON THE YIELD AND QUANTITY OF DRIP-IRRIGATED MUSK-AND WATERMELONS,
Dan, C.
Ministry of Agriculture, Beisan, Israel.
Proceedings of the Second International Drip Irrigation Congress, pp. 425-430,
July 1974. 8 tab.

Descriptors: *Melons, *Fertilization, *Crop response, Agriculture, Irrigation.

Trials were initiated to determine irrigation and fertilization practices to promote high muskmelon and watermelon yields of satisfactory quality. Yields were not affected by different amounts of irrigation water or by different irrigation schedules.

74:03F-018
THE IRRIGATION OF OLIVES BY DRIP AND OTHER IRRIGATION METHODS,
Dan, C.
Ministry of Agriculture, Beisan, Israel
Proceedings of the Second International Drip Irrigation Congress, pp. 491-496,
July 1974. 4 tab.

Descriptors: *Crop response, Agriculture, Irrigation.

Drip irrigated young trees gave higher and earlier yields before attaining full maturity, than trees irrigated by any other method. The number of emitters per tree was not found to be critical in the range of 4 to 8 emitters per tree. The yields of mature trees which were converted to trickle irrigation were generally somewhat higher than before.

74:03F-019
DRIP IRRIGATION: SURFACE AND SUBSURFACE COMPARED WITH SPRINKLER AND FURROW,
Davis, S. and Pugh, W.J.
United States Department of Agriculture, Riverside, California.
Proceedings of the Second International Drip Irrigation Congress, pp. 109-114,
July 1974. 3 fig, 2 tab, 2 ref.

Descriptors: *Furrow irrigation, *Sprinkler irrigation, *Subsurface irrigation, Melons, Agriculture, Irrigation.

This paper reports on four studies that compared crop response to various combinations of drip, subsurface, furrow and sprinkler irrigation. Study concludes that, 1) when the amount of water applied is near the consumptive use requirement, subsurface irrigation has greater production and better water use efficiency, 2) less water is needed for drip and subsurface irrigation than for furrow or sprinkler irrigation, because less water is lost to direct evaporation and deep percolation, and 3) the applicators used applied water equally well to the surface or subsurface soil, except where deposits from evaporation occurred.

74:03F-020
DRIPPER FLOW CONSISTENCY,
Davis, S. and Pugh, W.J.
United States Department of Agriculture, Riverside, California.
Proceedings of the Second International Drip Irrigation Congress, pp. 281-283,
July 1974. 6 fig.

Descriptors: *Flow characteristics, *Flow rates, *Application equipment Equipment, Agriculture, Irrigation.

Several different emitters have been checked for flow consistency volumetrically, both in time for the same emitter and for several emitters along the applicator line. Results of two years' study show many of the applicators vary more than +5% from the average. With the exception of a few drippers that were partially clogged or improperly manufactured, most of the drippers provided consistent water distribution both along the line and with time.

74:03F-021
SOIL SALINITY DISTRIBUTION IN DRIP AND SUBSURFACE IRRIGATED SUMMER SQUASH,
Davis, K.R. and Spencer, W.F.
United States Department of Agriculture, Riverside, California.
Proceedings of the Second International Drip Irrigation Congress, pp. 358-363,
July 1974. 3 fig, 2 tab, 4 ref.

Descriptors: *Salinity, *Subsurface irrigation, *Irrigation practices, *Soil water movement, Management, Agriculture, Irrigation.

Salt and water distribution patterns were determined around a porous tubing as part of a study to evaluate several drip and subsurface irrigation lines at Riverside, California. Generalized plot sampling after seasonal rainfall established initial soil salinity and water levels. A detailed scheme was employed for mid-season and end-season soil sampling. Soil salinity and water distributions before, during, and after the 1973 growing season of zucchini squash are discussed.

74:03F-022
DEVELOPMENT AND SCOPE OF DRIP AND SUBSURFACE IRRIGATION,
Deshmukh, M.T.
Udaipur University, India.
Proceedings of the Second International Drip Irrigation Congress, pp. 52-57, July 1974. 31 ref.

Descriptors: Agriculture, Irrigation, Subsurface irrigation, Salinity, Saline water

Drip irrigation is quite suitable for arid and semi-arid regions characterized by poor saline soil, saline irrigation water, and high evapotranspiration rates. In this method, water is applied slowly and continuously to the crops on the ground surface with the help of pipes having perforations or emitters fixed at suitable intervals along the length of the pipe. This paper reviews the developments in the drip method of irrigation.

74:03F-023
EVALUATION OF HYDRAULICS OF FLOW THROUGH PIPES OF VARYING SLOPES, LENGTHS AND ORIFICE PLACEMENTS,
Deshmukh, M.T. and Jain, M.L.
Udaipur University, India.
Proceedings of the Second International Drip Irrigation Congress, pp. 317-321, July 1974. 2 fig, 1 tab, 8 ref.

Descriptors: *Hydraulic design, Agriculture, Irrigation, Hydraulics, Irrigation design, Hydraulic equipment.

Polyethylene pipes with 1/2" diameter and 1/16" size perforations have been used to study the hydraulics of flow, under laboratory conditions. The variables considered for study were (i) length of the pipe (ii) spacing of perforations (iii) pipe slope (iv) placement of perforations (facing upward, downward and sidewise) and (v) operating pressure (up to 5 ft.). Three repeated readings have been taken for each test and validity of the results showing relationship of discharge with variables considered has been established with suitable tests.

74:03F-024
DRIP IRRIGATION IN LANDSCAPING AND SOIL EROSION CONTROL,
Farrell, M.D.
Kuluwai Irrigation Corporation, Haleiwa, Hawaii.
Proceedings of the Second International Drip Irrigation Congress, pp. 44-45, July 1974.

Descriptors: *Soil erosion, *Landscaping, Irrigation.

Article briefly discusses design, filtration, problems, and controls with drip irrigation in landscaping situations.

74:03F-025
CLOGGING OF DRIP SYSTEMS FROM METABOLIC PRODUCTS OF IRON AND SULFUR BACTERIA,
Ford, H.W. and Tucker, D.P.H.
Florida University, Lake Alfred, Florida.
Proceedings of the Second International Drip Irrigation Congress, pp. 212-214, July 1974.

Descriptors: *Clogging, *Iron bacteria, *Sulfur bacteria, Irrigation, Agriculture.

Numerous drip irrigation systems have been installed in central and south Florida citrus groves. Many have ceased to function properly because of filter and emitter clogging. The most serious clogging, involving water from shallow and deep wells, has been found associated with a sulfur bacteria. The long filamentous bacteria, stuffed with sulfur from the oxidation of hydrogen sulfide within the irrigation pipes, clog all small openings within a brief period of time. The white, slimy organic-sulfur-iron mass can only be dissolved in pyridine. Another serious clogging factor, from wells containing traces of ferrous iron, has been a filamentous gelatinous iron deposit (ochre) caused by iron bacteria. The sticky sludge adheres to filters and the grooves and orifices of emitters.

74:-3F-026
DRIP IRRIGATIONS INHERENT REQUISITE - WATER QUALITY,
Fraser, G.O.
Scientific Irrigation Systems, El Monte, California.
Proceedings of the Second International Drip Irrigation Congress, pp.81-85,

Descriptors: *Coagulation, *Flocculation, *Filtration, Agriculture, Irrigation.

Article discusses reasons why water quality is of the utmost importance and what factors cause deterioration of water quality. Methods of filtering irrigation water are presented.

74:03F-027
AN EXPLANATION FOR THE GROWTH ADVANTAGE OF DRIP IRRIGATION,
Freeburg, R.S., Cotter, D.J., and Urquhart, N.S.
New Mexico State University, Las Cruces, New Mexico.
Proceedings of the Second International Drip Irrigation Congress, pp. 265-270, July 1974. 2 fig, 3 tab, 6 ref.

Descriptors: *Diurnal, *Temperature, *Soil temperature, *Furrow irrigation, *Sweet corn, *Crop Response, Agriculture, Irrigation, Irrigation practices.

Soil, leaf, and air temperatures were measured for sweet corn during a 16-day period following emergence. The corn was grown in an experiment designed to compare trickle (drip) irrigation to furrow irrigation. There were significant differences between the temperature regimes produced by the two irrigation methods. The effects were especially notable in the soil temperatures. Based on a soil temperature of 80°F which research literature indicates to be optimum for corn growth, an integrated deviation from optimum was computed for each irrigation method. Deviations above the optimum at the two-inch depth were only 785 degree-hours for the trickle system as compared to 1238 degree-hours for the furrow system during the 16-day period. During this period, the growth rate of the crop under furrow irrigation was 84 percent of that under the trickle irrigation.

74:03F-028
EFFECTS OF NITROGEN FERTILIZER APPLICATIONS TO PART OF A ROOT SYSTEM,
Frith, G.J.T. and Nichols, D.G.
Victorian Department of Agriculture, Ferntree Gully, Australia.
Proceedings of the Second International Drip Irrigation Congress, pp. 434-436, July 1974. 1 tab.

Descriptors: *Nitrogen, *Fertilization, *Apples, *Root systems, Orchards, Irrigation, Agriculture, Irrigation water.

It is usual under trickle irrigation of mature fruit trees to have considerably less than the total root volume wetted. If satisfactory nutrition of these trees is to be achieved with fertilizer dissolved in the irrigation water, then the wetted roots must increase their efficiency of nutrient uptake in a manner similar to their increased water uptake. Trials with split root seedling apple trees grown in water culture has shown that the nitrogen uptake efficiency of roots is increased as the proportion of the root system supplied with nitrate nitrogen is decreased. The efficiency of water uptake from those parts of the root system supplied with nitrate nitrogen was also increased over the level of uptake on quarters without nutrients.

74:03F-029
IRRIGATION FOR BENCHES,
Furuta, T., Besemer, S., Jones, W.C., Strohman, R., and Mock, T.
California University, Riverside, California.
Proceedings of the Second International Drip Irrigation Congress, pp. 149-154, July 1974. 4 fig.

Descriptors: *Greenhouses, Horticultural crops, Agriculture.

A series of experiments were conducted on the modification of existing irrigation systems and the use of drip irrigation for crops grown in benches. Where the system was properly designed, excellent plant growth and yield resulted from the use of modified nozzle irrigation systems, and from the use of drip systems, both individual emitters and tubes with small orifices. As measured by plant performance, water was more uniformly distributed in the soil where drip or the modified nozzle system was used, compared to established irrigation systems. Even with soils amended with large volumes of organic matter, uniform distribution of water occurred, even though the surface between emitters was dry. Also excellent crops were produced in a soil that would be considered too tight or heavy for use in a bench. Considerable savings on the amount of water used and a corresponding reduction of the volume run-off resulted.

74:03F-030
IRRIGATION FOR CONTAINER GROWING,
Furuta, T., Branson, R., Jones, W.C., Strohman, R., Mock, T., and Ramadan, I.
California University, Riverside, California.
Proceedings of the Second International Drip Irrigation Congress, pp. 155-158, July 1974.

Descriptors: *Nutrients, *Root development irrigation, Greenhouses, Salinity.

Trickle irrigation and modifications have been used for container growing, especially under greenhouse conditions, for more than a decade. Microtubing has been generally used. Difficulties with uniform wetting of the entire soil mass had been encountered. This and other problems has limited the use of trickle irrigation. With the development of emitters for containers, it became possible to study the use of drip irrigation for container growing. A series of experiments was conducted to study the soil mixture-fertilization-irrigation subsystem, varying each factor simultaneously. Larger plants--tops and roots--were noted under drip irrigation. These plants had higher N content initially and lower Na and Cl content late in the experiment. Root distribution within the container was also influenced with more roots in the center of the ball. Considerably less water was used with drip irrigation than with overhead sprinkling. The method of irrigation influenced salinity, nutrient content of drainage water and the wetting pattern in the soil.

74:03F-031
A CONSTANT MICRO SOURCE OF MOISTURE AS A COMPONENT ON A GRADIENT SYSTEM FOR A HIGH LEVEL PRODUCTION,

Geraldson, C.M.
Florida University, Bradenton, Florida.
Proceedings of the Second International Drip Irrigation Congress, pp. 131-136,
July 1974. 4 fig, 4 ref.

Descriptors: *Nutrients, Agriculture, Irrigation.

The objective of this study was to evaluate the use of a constant micro source of moisture which could be used as an alternative to a constant water table in establishing nutrient gradients for optimal production. Constant moisture was supplied by drip (trickle system) or by micro pore tubing. Soluble nutrients were supplied primarily by banded placement on the soil bed surface. Relative placement of fertilizer, moisture and plants as the major variables were evaluated in conjunction with different soils as well as the sources of moisture. A consistent high level production of vegetables and flowers was attained by integrating contributing components such as soil, moisture, fertilizer and plants to establish the desired gradient system. The resultant effect in conjunction with synthetic mulch as a protective component minimizes or eliminates these components as contributing variables.

74:03F-032
DRIP AND FURROW IRRIGATION STUDIES ON SUGARCANE,
Gerard, C.J.
Texas Agricultural Experiment Station, Weslaco, Texas.
Proceedings of the Second International Drip Irrigation Congress, pp. 329-331,
July 1974. 3 ref.

Descriptors: *Sugarcane, *Furrow irrigation, *Crop response, Texas, Irrigation, Agriculture.

Research was conducted to evaluate the influences of drip and furrow irrigation on growth and yield of sugarcane in 1972 and 1973 in the Lower Rio Grande Valley of Texas. Drip irrigation treatments were 0, 25, 50, 75, and 100 and 0, 50, 75, 100, and 125% pan evaporation in 1972 and 1973, respectively. Yield of sugarcane was a linear function of applied water in 1972 with yields ranging from 35 to 51 tons per acre. Drip irrigation treatments are greater than or equal to 0.5 pan evaporation maintained rapid stalk elongation in early May and June in 1972. Rapid stalk elongation in July, August and September was maintained when the water applied was greater than or equal to 0.75 pan evaporation. Soil moisture, salinity conditions and root growth as influenced by treatments, emitter sites and soil depths were evaluated. These findings and their implications are discussed.

74:03F-033
HYDRAULIC AND MECHANICAL PROPERTIES OF DRIPPERS,
Gilaad, Y., Krystal, L., and Zanker, K.
Israel Center of Water Works Appliances, Tel-Aviv, Israel.
Proceedings of the Second International Drip Irrigation Congress, pp. 311-316,
July 1974. 1 tab.

Descriptors: *Hydraulic properties, *Hydraulic equipment, *Hydraulic design, *Mechanical properties, Hydraulics, Agriculture, Irrigation.

Article discusses research dealing with the hydraulic, mechanical, and functional requirements of the various types of emitters available based on hydraulic tests performed and experience accumulated in the field. The following hydraulic properties have a direct influence of the operation of drippers: the relationship between flow rate and pressure, resistance to the flow of water in the tubing at the place of insertion of the dripper, and shape and size of the water passage in the dripper.

74:03F-034
OPTIMUM LATERAL PLACEMENT FOR SUBSURFACE IRRIGATION SYSTEMS,
Gilley, J.R. and Allred, E.R.
Minnesota University, St. Paul, Minnesota.
Proceedings of the Second International Drip Irrigation Congress, pp. 234-239,
July 1974. 6 ref.

Descriptors: *Subsurface irrigation, *Mathematical models, *Irrigation design, Irrigation, Irrigation efficiency, Irrigation systems, Agriculture.

Design of a subsurface irrigation system requires both the proper placement of the lateral line in the soil profile and proper lateral discharge. The lateral placement depends on the nature of the soil-moisture movement from the applicator and the extraction pattern of the irrigated crop. The optimum location of the laterals will therefore vary with soil type and the crop being irrigated. A mathematical model describing soil-moisture movement during subsurface irrigation has been developed. The results of the portion of the model describing infiltration from the subsurface lateral compare quite favorably with data available in the literature. A series of one dimensional sinks, to simulate soil-moisture extraction by plants, has been combined with the infiltration model to obtain a model of soil-moisture movement during subsurface irrigation. The model was used to determine optimum lateral placement as a function of soil type and crop root zone depth to obtain the desired crop extraction patterns. Results of the model indicate the optimum lateral placements also have higher irrigation efficiencies than other placement values. These variables were used to develop design curves relating lateral depth, spacing and discharge to soil type and crop extraction pattern. Results also indicate that for proper design, lateral depth is more important than lateral spacing.

74:03F-035
STRIP CULTIVATION OF THE AREA WETTED BY DRIP IRRIGATION IN THE ARAVA DESERT,
Goldberg, S.D. and Uzrad, M.
The Hebrew University of Jerusalem, Rehovat, Israel.
Proceedings of the Second International Drip Irrigation Congress, pp. 142-147,
July 1974.

Descriptors: *Strip cropping, *Saline water, *Salinity, *Sprinkler irrigation, Melons, Irrigation practices, Irrigation, Agriculture.

Drip irrigation cultivation is in effect strip cultivation and in fact it represents almost the most intensive form of cultivation. Throughout the growing season the cultivated strip gets a most intensive set of treatments. Under arid climatic conditions in light soils and with saline water (like in the Arava), it is safe to assume that these strips will undergo considerable chemical changes which would materially differ from the intermediary uncultivated strips. The problem posed was whether the cultivated strips were better, or worse, or of no difference compared to the uncultivated strips. Results show that the cultivated strips were superior to the uncultivated strips.

74:03F-036
FERTILIZER APPLICATIONS WITH DRIP IRRIGATION,
Grobbelaar, H.L. and Lourens, F.
Agriplas Limited, Republic of South Africa.
Proceedings of the Second International Drip Irrigation Congress, pp. 411-415,
July 1974. 3 tab.

Descriptors: *Fertilization, *Irrigation practices, Irrigation, Agriculture.

It has been found that the application of fertilizer mixtures through a drip irrigation system is not only feasible, but can be very beneficial. Fertilizer mixtures must not cause blockage, must be water soluble, must leave no residue in the fertilizer dispenser, and must be easy to handle.

74:03F-037
RESEARCHES AND APPLICATIONS ON DRIP IRRIGATION AND SIMILAR METHODS IN ITALY,
Grossi, P.
Pisa University, Pisa, Italy.
Proceedings of the Second International Drip Irrigation Congress, pp. 46-51, July 1974.

Descriptors: Irrigation systems, Agriculture, Irrigation.

Research progress with trickle irrigation is discussed along with the hydraulic, pedological, and agronomical results of this research.

74:03F-038
DRIP IRRIGATION-WORLDWIDE,
Gustafson, C.D., Marsh, A.W., Branson, R.L., and Davis, S.
California University, San Diego, California.
Proceedings of the Second International Drip Irrigation Congress, pp. 17-20, July 1974. 1 fig.

Descriptors: *History, *Irrigation practices, Irrigation systems.

Water is a precious commodity. Good water supplies are always in demand. All around the world, problems with water are: short supply, poor quality and/or expensive. In reviewing the development of drip irrigation, it is apparent that the greatest interest is in areas where there is a problem with water supplies. Poor soils or steep terrain also encourages the use of drip irrigation. Drip irrigation is not new. It has been used for years. What is new, however, is its application to modern agriculture. On a commercial scale in the United States, it can be traced back to 1969-70. That was not the beginning, however, since many industries have been using some type of drip irrigation for a long time. Drip irrigation had its beginning in the greenhouse culture after World War II in the United Kingdom. In the late 1950's and early 60's, Richard Chapin, New York; Dr. Symcha Blass, Israel; and Dr. Vollmer Hansen, Denmark, simultaneously were perfecting what is commonly known as the spaghetti system.

74:03F-039
DRIP IRRIGATION EXPERIMENT ON AVOCADOS,
Gustafson, C.D., Marsh, A.W., Branson, R.L., and Davis, S.
California University, San Diego, California.
Proceedings of the Second International Drip Irrigation Congress, pp. 443-445, July 1974.

Descriptors: *Crop response, *Crop productivity, *Salinity, Sprinkler irrigation, Cost comparisons, Diseases, Irrigation, Agriculture.

In June 1970, an irrigation project was initiated to compare drip irrigation with the conventional spitter-sprinkler system, commonly used in avocado orchards. Evaluation of the two methods include: 1) a comparison of growth and productivity; 2) salinity accumulation and distribution in soils under each system; 3) annual costs to operate each system; 4) determine if trees are more or less susceptible to the avocado root rot disease; and 5) observe operation of equipment.

74:03F-040
STAKED TOMATO DRIP IRRIGATION IN CALIFORNIA,
Hall, B.J.
California University, San Diego, California.
Proceedings of the Second International Drip Irrigation Congress, pp. 480-486, July 1974. 6 tab, 6 ref.

Descriptors: *Tomatoes, Furrow irrigation, Irrigation systems, Irrigation practices, Crop response, Irrigation, Agriculture.

Six staked tomato drip irrigated field trials, where properly grown, resulted in slightly higher yields and appreciable water savings, compared to furrow applications. Drip irrigation supplied water more uniformly which resulted in more even plant growth. Cultural operations can be carried out in the drip irrigated crops at any time, while close coordination of these operations is essential when using furrow or sprinkler irrigations.

74:03F-041
SPRING CUCUMBER DRIP VS. FURROW IRRIGATION,
Hall, B.J.
California University, San Diego, California.
Proceedings of the Second International Drip Irrigation Congress,pp. 486-490, July 1974. 1 tab, 6 ref.

Descriptors: *Fertilization, *Furrow irrigation, *Crop response, Irrigation, Agriculture.

Two field trials conducted on the early spring cucumbers started and grown in plastic row covers indicate that drip irrigation can successfully produce good yields. Less water can be used in producing as high or better yields with drip irrigation. Slow release fertilizer resulted in good yields, yet the plants appeared to run short during the last two or three weeks. Placing the drip line in the bottom of a 1 1/2 to 2-inch narrow furrow appeared to reduce the mature fruit pressure on the drip lines in bush culture.

74:03F-042
VEGETABLE PRODUCTION AND WATER-USE EFFICIENCY AS INFLUENCED BY DRIP, SPRINKLER, AND FURROW IRRIGATION METHODS,
Hanson, E.G. and Patterson, T.C.
New Mexico University, Las Cruces, New Mexico.
Proceedings of the Second International Drip Irrigation Congress, pp. 97-102, July 1974.

Descriptors: *Sweet corn, *Onions, *Crop response, *Irrigation practices, *Vegetable crops, *Irrigation systems, *Sprinkler irrigation, *Subsurface irrigation, *Furrow irrigation, *Soil moisture, Salinity, Irrigation, Agriculture.

Sweet corn and onions have been grown on replicated plots with four methods of irrigation: drip, subsurface, sprinkler, and furrow. Half of the plots have been irrigated to maintain the soil moisture tension at or below 0.20 atmospheres, and the other half at or below 0.60 atmospheres. Yield, quality, and water-use efficiency pertaining to each crop is reported for three growing seasons. Changes in soil salinity are discussed.

74:03F-043
DRIP IRRIGATION DESIGN CRITERIA FOR TREE CROPS IN FLORIDA AND OTHER HUMID REGIONS,
Harrison, D.S. and Myers, J.M.
Florida University, Gainsville, Florida.
Proceedings of the Second International Drip Irrigation Congress, pp. 33-37, July 1974. 11 ref.

Descriptors: *Orchards, *Crop response, *Florida, *Humid area, Irrigation practices, Citrus fruits, Irrigation, Agriculture, Irrigation systems, Irrigation design.

Drip irrigation has been installed on approximately 4,000 acres of citrus and other orchard crops in Florida during the past 2 years. Some of the reasons for increased interest in this method of irrigation are: (1) conservation of water, (2) labor savings, (3) lower operating costs, and (4) lower power requirements. Some problems are: (1) improper water filtration, (2) research data on crop response not readily available, (3) vandalism, (4) unavailability of fully tested design criteria, (5) emitter spacing, and (6) expected life. Two years research data in Florida on strawberries, and one year on tomatoes show that response to drip irrigation is comparable to other application methods and water savings as much as 60-70% may be expected. Fertilizer response, when applied through the drip system, has been outstanding.

74:03F-044
PLANT WATER REQUIREMENTS AS RELATED TO TRICKLE IRRIGATION,
Hoare, E.R., Garzoli,K.V., and Blackwell, J.
Proceedings of the Second International Drip Irrigation Congress, pp. 323-328, July 1974. 3 tab, 10 ref.

Descriptors: *Water requirements, *Irrigation systems, Irrigation design, Irrigation practices, Irrigation, Agriculture.

Trickle irrigation differs from spray and flood irrigation in that water is supplied in small amounts at frequent intervals in order to satisfy, as closely as possible, the plants' immediate needs. This is in contrast to other forms of irrigation in which large quantities of water are supplied, following which a gradual drying of the soil takes place, and subsequent irrigation is carried out to replenish the reservoir of soil moisture. The difference in these two approaches to irrigation means that current methods of estimating the water requirements of crops requires further evaluation. Not only does the water requirement vary with different climatic conditions, age of the plants and the season, irrespective of the method of irrigation, but the use of trickle irrigation imposes a further variation due to its particular effect on the soil-plant-atmosphere complex. The water requirements of plants under trickle irrigation are examined and ways are suggested in which these may be calculated from evaporation data, soil properties and other characteristics specific to the particular crop. Reference is also made to the use of trickle irrigation in particular situations, and how the water requirements in such cases can best be satisfied.

74:03F-045
SALINITY MANAGEMENT FOR HIGH FREQUENCY IRRIGATION,
Hoffman, G.J., Rawlins, S.L., Oster, J.D., and Merrill, S.D.
United States Department of Agriculture, Riverside, California.
Proceedings of the Second International Drip Irrigation Congress, pp. 372-375, July 1974. 4 fig.

Descriptors: *Salinity, *Saline soil, *Saline water, *Leaching, Grain sorghum, Lettuce, Wheat, Crop response, Irrigation practices, Irrigation, Agriculture.

A field plot experiment designed to determine the minimum leaching required to maintain crop yields under high frequency irrigation is described. Two varieties of wheat, grain sorghum, and lettuce are being grown in rotation each year in six replicated leaching fraction treatments. Precise measurements of the volume and salt concentration of the irrigation and drainage waters along with in-situ soil salinity measurements and crop yield are reported.

74:03F-046
DESIGNING TRICKLE IRRIGATION LATERALS FOR UNIFORMITY,
Howell, T.A. and Hiler, E.A.
Texas University, College Station, Texas.
Proceedings of the Second International Drip Irrigation Congress, pp. 299-304, July 1974. 3 fig, 6 ref.

Descriptors: *Uniformity coefficient, *Uniform flow, *Irrigation design, Irrigation systems, Design criteria, Design flow, Irrigation, Agriculture.

Proper design of trickle irrigation laterals for desired uniformity is important to prevent under-irrigation, with resulting crop damage, or over-irrigation, with resulting water losses of drainage and runoff. Recently several papers have presented trickle irrigation design data and methods; yet a simple design equation for directly determining maximum lateral lengths for different lateral slopes, trickle emitter types, pipe sizes, and desired uniformity is not available. Design equations, based on standard principles, fluid mechanics, and graphs are presented which can be used to determine maximum trickle irrigation lateral lengths for selected uniformities. The maximum lateral length for a given uniformity is given as a power function (linear log-log) of either emitter spacing of number of emitters per lateral. Engineering design applications for this method are given in the form of specific examples. Implications and assumptions inherent in the method are discussed.

74:03F-047
INVESTIGATIONS IN SUGARCANE FERTILIZATION BY DRIP IRRIGATION IN HAWAII,
Isobe, M.
Hawaiian Sugar Planters Association, Honolulu, Hawaii.
Proceedings of the Second International Drip Irrigation Congress, pp. 405-510, July 1974. 3 tab.

Descriptors: *Sugarcane, *Fertilization, Hawaii, Nitrogen, Subsurface irrigation, Irrigation practices, Irrigation, Agriculture.

Research was initiated in Hawaii to determine efficient ways to fertilize sugarcane under drip irrigation. Paper reports on improvement of fertilizer efficiency and the use of aqua ammonia, the cheapest source of nitrogen available on the market.

74:03F-048
EVALUATION OF A TRICKLE IRRIGATION SYSTEM,
Karmeli, D. and Keller, J.
Technion, Haifa, Israel.
Proceedings of the Second International Drip Irrigation Congress, pp. 287-292, July 1974. 1 tab.

Descriptors: *Uniformity, Soil moisture, Evaluation, Performance, Filtration, Irrigation practices, Irrigation efficiency, Irrigation operation and maintenance, Irrigation systems, Irrigation, Agriculture.

Factors determining performance of the system i.e. filtration quality, pressure and soil moisture distributions, are analyzed. Techniques for the evaluation of a system design or field performance are described and an equation to calculate the emission uniformity, EU, of a trickle system is presented. Results of field tests and design evaluations are summarized and criteria established. Relationships between EU and soil volume values as well as irrigation regimes (application rates and intervals) are discussed.

74:03F-049
TRICKLE IRRIGATION DESIGN FOR OPTIMAL SOIL WETTING,
Keller, J. and Karmeli, D.
Utah State University, Logan, Utah.
Proceedings of the Second International Drip Irrigation Congress, pp. 240-245, July 1974. 2 fig, 2 tab, 3 ref.

Descriptors: *Irrigation design, Soil moisture, Evapotranspiration, Flow rates, Design criteria, Economics, Irrigation, Agriculture.

The general relationship between the percentage area wetted and crop productivity is discussed and the recommended trickler spacing for achieving the desired soil wetting is presented. The number of operating blocks (stations or sub-units) required to obtain the desired soil wetting is developed considering ET demands and system capacity constraints. The effect of the number of blocks on hydraulic features of the network and the relative economic effect is considered.

74:03F-050
TRICKLE IRRIGATION IN MICHIGAN ORCHARDS,
Kesner, C.D. and Kenworthy, A.L.
Michigan State University, East Lansing, Michigan.
Proceedings of the Second International Drip Irrigation Congress, pp. 272-274, July 1974.

Descriptors: Irrigation practices, Irrigation systems, Michigan, Orchards.

The concept of trickle irrigation is being rapidly accepted by Michigan fruit growers. A major source of water is from small existing wells previously used for cooling sour (red tart) cherries at harvest time and other purposes. Lakes, ponds, rivers, and creeks also serve as water sources. Pressure regulators or gate valves were originally used to control in-line pressure but the present trend is toward flow regualting valves in each row lateral. The primary emitter system in Michigan is the microtube with .025, .035, .036, or .045 inch I.D. tubes being the most popular. An illustrated presentation demonstrates the techniques used in many different installations.

74:03F-051
WEED CONTROL UNDER DRIP IRRIGATION IN ORCHARD AND VINEYARD CROPS,
Lange, A., Aljibury, F., Fischer, B., Humprey, W., and Otto, H.
Proceedings of the Second International Drip Irrigation Congress, pp. 422-424, July 1974.

Descriptors: *Herbicides, Orchards, Irrigation practices, Irrigation, Agriculture.

Conventional herbicide applications in orchards and vineyards under drip irrigation have been somewhat unsuccessful. Annual applications of most herbicides have broken down in the moist area close to the dripper leaving a vigorous small circle of weed growth by summer. Herbicides differ in their rates of breakdown under drip irrigation when compared to furrow and sprinkler. Atrazine showed the greatest response to breaksown under continuously wet soils. Napropamide was affected least bu wet soils. Trifluralin, profluralin, and norflurazon were intermediate. Numerous herbicide treatments have been evaluated under drip irrigation. The results of several of these are discussed.

74:03F-052
SOIL MOISTURE DISTRIBUTION AND DEPLETION IN AN APPLE ORCHARD IRRIGATED BY TRICKLERS,
Levin, I., Assaf, R., and Bravado, B.
The Hebrew University of Jerusalem, Rehovat, Israel.
Proceedings of the Second International Drip Irrigation Congress, pp. 252-257, July 1974. 4 fig, 1 tab, 4 ref.

Descriptors: Irrigation practices, *Soil water movement, Irrigation systems, Frequency, Orchard, Apples, Crop response, Irrigation, Agriculture.

Four treatments of trickle irrigation methods were applied in an apple orchard on heavy soil. The treatments differed in water discharge rate of the tricklers (4 and 8 liter/hour), distances between the outlets on the lateral lines (1.25 m and 2 m) and irrigation frequency (1, 3 and 7-day intervals). In all treatments the amount of water applied was on the basis of 10 mm/day consumptive use. Soil moisture content fluctuations in the upper 60 cm layer before, during and after irrigation were frequently measured. The distance wetted from the trickler was linearly dependent on the duration of the single irrigation and the discharge rate of the trickler: 65 cm, 80 cm, and 120 cm after 14, 24 and 70 hours of irrigation at a 4 liter/hour discharge rate, respectively; and 120 cm after 40 hours at a 8 liter/hour discharge rate. The soil moisture content at the end of the irrigation dropped gradually from under the trickler to the farthest distance wetted, where about 90% of field capacity was reached. After the termination of the irrigation, the soil moisture content depleted gradually to the level before the beginning of the irrigation - at all distances from the tricklers and in all treatments. The results indicate that there was deep drainage below the root zone in the area under the tricklers in all treatments.

74:03F-053
APPLICATION OF FERTILIZER THROUGH DRIP IRRIGATION SYSTEMS IN WEST TEXAS,
Lindsey, K.E.and New, L.L.
Texas University, Lubbock, Texas.
Proceedings of the Second International Drip Irrigation Congress, pp. 400-404, July 1974.

Descriptors: *Fertilization, *Pecans, Irrigation systems, Zinc, Crop response, Irrigation, Agriculture.

Zinc chelate applications to pecan trees were made through several types of systems on several soil types. Comparisons were made with customary spray applications of Zn. Effectiveness of applications was measured by leaf analysis and trunk growth measurements. Examination of the effectiveness of several of the injection systems was done by analyzing water emitted at timed intervals after injection of Zn materials.

74:03F-054
EFFECTS OF DRIP IRRIGATION ON SOIL-WATER-PLANT RELATIONSHIP,
Manfrinato, H.A.

Escola Superior de Agricultura, Sao Paulo, Brazil.
Proceedings of the Second International Drip Irrigation Congress, pp. 446-451, July 1974. 1 fig, 4 tab, 9 ref.

Descriptors: *Infiltration, *Moisture content, *Soil water movement, *Soil-water-plant relationships, Agriculture.

Soil columns, prepared in the laboratory, by packing sieved and air dried soil into cylinder tubes were used to study the distribution of moisture content at the moment of infiltration. Drops of water, were applied simulating rain, at eight differernt intensities, called treatments, with two repetitions. When the water application rate was continually reduced throughout the treatments, the moisture content also diminished and vice versa. It was also concluded that when the rain application intensity was decreasing to a very small rate, the moisture content had such a slow reduction, as if going to a limit, which was found to be the soil field capacity.

74:03F-055
WATER USE BY DRIP AND SPRINKLE IRRIGATED AVOCADOS RELATED TO PLANT COVER, EVAPORATION AND AIR TEMPERATURE,
Marsh, A.W., Gustafson, C.D., Davis, S., Branson, R.L., and Strohman, R.A.
California University, Riverside, California.
Proceedings of the Second International Drip Irrigation Congress, pp. 346-350, July 1974. 2 tab, 5 ref.

Descriptors: *Consumptive use, *Sprinkler irrigation, *Air temperature, *Evaporation, Tensiometers, Irrigation systems, Irrigation practices, Irrigation, Agriculture.

Water application to the avocados has been closely controlled by relating it to tensiometer readings. A sufficiency has been maintained while limiting excesses. In 1973, the drip applications have been automatically controlled by electrified tensiometers that provide signals for a controller. The measured applications are thought to represent the actual water requirement for each irrigation system as closely as it can be determined. The correlation of measured water use to evaporation from a class A pan is shown for each irrigation method as influenced by varying air temperature, percentages of plant cover, and period of the year.

74:03F-056
CHEMICAL TREATMENT OF DRIP IRRIGATION WATER,
McElhoe, B.A. and Hilton, H.W.
Hawaiian Sugar Planters' Association, Honolulu, Hawaii.
Proceedings of the Second International Drip Irrigation Congress, pp. 215-220, July 1974. 2 fig, 2 tab.

Descriptors: *Microorganisms, *Bacteria, *Plugging, *Orifice flow, *Orifices, Irrigation, Agriculture, Irrigation efficiency, Irrigation systems, Irrigation water.

Bacteria and other microorganisms in water are contributors to orifice plugging. Their skeletons, the slimes they produce, and their metabolic products are the glue that binds fine soil particles to the walls of the tube. Chenical treatment can arrest the agglomeration process and significantly reduce plugging.

74:03F-057
AN INVESTIGATION ON THE USE OF DRIP IRRIGATION FOR THE ESTABLISHMENT OF MULTI-

**PURPOSE PARKS (GREEN BELTS AROUND THE CITIES) IN IRAN,**
**Mehdizadeh, P. and Tamaddoni-Jahromi, S.**
**Research Institute of Forests and Rangelands, Tehran, Iran.**
Proceedings of the Second International Drip Irrigation Congress, pp. 462-468,
July 1974. 5 fig, 2 tab.

Descriptors: *Furrow irrigation, *Crop response, *Parks, Irrigation, Irrigation systems, Irrigation practices, Forestry, Forests, Forest management.

Paper deals with the application of a "home-made" drip irrigation system in a multipurpose forest park near Tehran. The study was initiated as a pilot trial to determine: (1) if drip irrigation should be considered for irrigating forest species in the parks and green belts, of Iran, (2) plant responses to drip irrigation of green belts, and (3) possible water savings . Although some suppression of height growth was found, seedlings remained healthy. The amount of irrigation water used was reduced by 85% as compared to the furrow irrigation system used previously.

74:03F-058
TREE AND CROP RESPONSE TO DRIP IRRIGATION,
Middleton, J.E., Proebsting, E.L., Roberts, S., and Emerson, F.H.
Washington State University, Prosser, Washington.
Proceedings of the Second International Drip Irrigation Congress, pp. 468-473,
July 1974. 5 fig, 3 tab, 3 ref.

Descriptors: *Orchards, *Crop response, *Fruit crops, Salinity, Irrigation system, Irrigation practices, Irrigation, Agriculture.

Bearing "Early Italian" prune trees performed normally with 60 and 80 gallons per tree per day using continuous drip irrigation. With 20 and 40 gallons per tree per day the fruit was smaller, better colored and earlier with higher soluble solids. In the second year, the two lower rates greatly reduced bearing surface and yields. Leaf moisture data indicated no difference on the four quadrants of the tree when all water was applied at one point. Twelve hour daily applications were compared to continuous applications the second year. There were some soluble salts on the non-saline soil which were reduced measurably by movement away from the center of the drip area as the season progressed. Soil moisture movement was recorded. Growth response of first year apple trees to drip and sprinkler irrigation at comparative application frequencies and amounts was similar.

74:03F-059
TRICKLE IRRIGATION ON YOUNG PEACH TREES,
Mitchell, P.D. and Black, J.D.F.
Victorian Department of Agriculture, Ferntree Gully, Australia.
Proceedings of the Second International Drip Irrigation Congress, pp. 452-455,
July 1974. 8 fig.

Descriptors: *Peaches, *Crop response, *Growth rates, Root distribution, Evaporation, Orchards, Irrigation systems, Irrigation practices, Irrigation, Agriculture.

Two field trails on young peach trees are described. Trial A. The effects of supplying 9, 18, 36, or 72 ℓ of water per day to newly planted peach trees regardless of rainfall and evaporation demonstrate that these factors cannot be ignored in soils of imperfect drainage. Trees died under the highest rate, were severely damaged at the second highest rate, showed some root damage under the second lowest rate but grew better at this rate than at the lowest rate. Trial B. Growth of peach trees trickle irrigated daily or after 2.5 or 5 cm net evaporation intervals are compared. Response was less at the 5 cm interval than at the 2.5 cm or daily intervals. Root density in the wetted root zone was highest under the daily interval and least under the 5 cm interval. A significant linear relationship is established between trunk area increase and water applied per unit of trunk area per unit of evaporation. The treatment limit in this trial of 2.5 ℓ per sq. cm. trunk area per cm evaporation is to be extended in further trials.

74:03F-060
AUTOMATIC DRIP IRRIGATION FOR GREENHOUSE TOMATO PRODUCTION IN WEST TEXAS,
New, L. and Roberts, R.
Texas A&M University, Lubbock, Texas.
Proceedings of the Second International Drip Irrigation Congress, pp. 159-164,
July 1974. 1 fig.

Descriptors: *Crop response, *Tomatoes, *Automatic control, *Automation, Greenhouses, Irrigation systems, Irrigation, Agriculture.

Soil moisture sensors are used to automatically control the operation of drip irrigation systems and maintain optimum moisture levels in West Texas tomato greenhouses. Up to ten thousand square feet of growing area is being successfully irrigated by one sensor. Time clocks cause intermittent irrigation which helps prevent overwatering, puddling and runoff. Water flow control valves limit drip emitter water application rates to 1.0 to 1.5 gallons per hour.

74:03F-061
A STUDY ON DIFFERENT APPLICATION PROCEDURES OF DRIP IRRIGATION ON TOMATO CULTIVATION,
Noyola, F.T.
Proceedings of the Second International Drip Irrigation Congress, pp. 508-511,
July 1974.

Descriptors: *Tomatoes, *Crop production, *Crop response, Irrigation systems, Irrigation practices, Irrigation, Agriculture.

Article discusses results of a study on tomatoes to determine reasonable application procedures of drip irrigation water.

74:03F-062
DRIP IRRIGATION AND AUTOMATION TOOLS IN EFFICIENT USE OF WATER POLICY,
Paldi, H.
Ministry of Agriculture, Safad, Israel.
Proceedings of the Second International Drip Irrigation Congress, pp. 29-32,
July 1974.

Descriptors: *Automation, *Water policy, *Water conservation, Irrigation systems, Irrigation, Agriculture.

Article discusses water savings in Israel with drip irrigation, long range irrigation plans for Israel, and irrigation system automation.

74:03F-063
IRRIGATION RETURN FLOW AS INFLUENCED BY DRIP IRRIGATION,
Patterson, T.C. and Wierenga, P.J.
New Mexico State University, Las Cruces, New Mexico.
Proceedings of the Second International Drip Irrigation Congress, pp. 276-381,
July 1974. 2 fig, 3 tab, 4 ref.

Descriptors: *Return flow, *Water quality, *Salinity, *Surface irrigation, *Saline water, *Saline soil, New Mexico, Texas, Irrigation practices, Irrigation systems, Irrigation, Agriculture.

Deterioration of water quality in the Rio Grande is a major problem for water users in New Mexico and Texas. From near Santa Fe, New Mexico to El Paso, Texas, a distance of 270 miles, the total of dissolved solids increases from 221 ppm to 787 ppm while while the percent of sodium increases from .25 near Santa Fe to 52 at El Paso. The deterioration in quality is due to the return of lower quality drainage water from the irrigated areas to the river. This paper describes a project designed to determine, under field conditions, rates of water and salt movement in the soil and subsequently to the drains as affected by frequency and amount of trickle irrigation, as compared to frequency and amount of surface water application. Both return flow quality and quantity are evaluated.

74:03F-064
FORMATION OF BLOCKAGES IN DRIP IRRIGATION SYSTEMS: THEIR PREVENTION AND REMOVAL,
Pelleg, D., Lahav, N., and Goldberg, D.
Israel Center of Waterworks Appliances, Israel.
Proceedings of the Second International Drip Irrigation Congress, pp. 203-208, July 1974. 8 fig, 3 tab, 6 ref.

Descriptors: *Clogging, Irrigation systems, Irrigation practices, Irrigation, Agriculture.

Clogging is one of the most severe problems associated with trickle irrigation systems. The different kinds of clogging are described along with the reasons for clogging. Methods of preventing clogging are given, and ways of cleaning systems after clogging has occurred are discussed.

74:03F-065
HIGH-FREQUENCY POROUS TUBE IRRIGATION FOR WATER-NUTRIENT MANAGEMENT IN HUMID REGIONS,
Phene, C.J.
United States Department of Agriculture, Florence, South Carolina.
Proceedings of the Second International Drip Irrigation Congress, pp. 166-171, July 1974. 6 fig, 1 tab, 8 ref.

Descriptors: *Sweet corn, *Crop response, *Subsurface irrigation, Nitrogen, Automation, Irrigation efficiency, Nutrients, Furrow irrigation, Sprinkler irrigation, Irrigation practices, Irrigation systems.

A plastic porous tube and an electronic soil matric potential sensor supplied sweet corn with nutrients and water automatically by controlling the water content of a limited volume of root-zone soil. Sweet corn yield and water-use efficiency obtained with high-frequency porous tube irrigation systems were compared with those obtained from high-frequency sprinkler and furrow irrigation systems under similar irrigation control and fertility. In another experiment, sweet corn yield, plant nitrogen uptake, and soil NO3(-) movement were studied under controlled soil matric potential for various application rates of N and K. Ear yield with high-frequency porous tube irrigation was 10.5 and 12.6% greater than ear yield obtained with furrow and sprinkler irrigation, respectively. Water-use efficiency was 37 and 54% higher for sensor controlled high-frequency porous tube irrigation than for furrow and sprinkler irrigation.

74:03F-066
CHAMBER METHOD FOR DRIP IRRIGATION SYSTEM DESIGN AND INSTALLATION PROCEDURE,
Pira, E.S.
Massachusetts University, Amhurst, Massachusetts.
Proceedings of the Second International Drip Irrigation Congress, pp. 121-126, July 1974. 4 fig, 2 tab, 2 ref.

Descriptors: *Head loss, *Design criteria, *Irrigation design, Irrigation methods, Flow rates, Irrigation, Agriculture.

High pressure water is supplied through a "quick-fill" and pressure reducing device to a low pressure chamber. A minimal pressure drop in the chamber produced a relatively uniform discharge rate from the drippers. This paper deals with the practical field installations based on laboratory tests, field tests and simulation model. System design criteria, components, materials, detailed illustrations and installation procedures are presented.

74:03F-067
MOVEMENT OF WATER AND SALTS UNDER HIGH FREQUENCY IRRIGATION,
Raats, P.A.C.
United States Salinity Laboratory, Riverside, California.
Proceedings of the Second International Drip Irrigation Congress, pp. 222-227,
July 1974. 5 fig, 14 ref.

Descriptors: *Soil water movement, *Salinity, *Infiltration, Irrigation systems, Irrigation, Agriculture.

Many modern irrigation systems deliver water at short intervals, in space as well as in time. Theoretical analyses show that the remaining variations are damped rapidly. Consequently, steady, one-dimensional movement and uptake is used as a basis for further analysis. Qualitative features of possible steady pressure head and water content profiles are discussed. Specific calculations for various leaching fractions and amounts of capilary rise from a water table are based on empirical, but realistic models for the dependence of the hydraulic conductivity upon the pressure head and for the spatial distribution of the rate of uptake. The resulting salinity profiles are also calculated. The results are compared with earlier, more approximate calculations.

74:03F-068
THE PROGRESS AND PROBLEMS OF DRIP IRRIGATION IN ISRAEL,
Rawitz, E. and Hillel, D.
The Hebrew University of Jerusalem, Rehovat, Israel.
Proceedings of the Second International Drip Irrigation Congress, pp. 23-28,
July 1974. 18 ref.

Descriptors: Crop response, Design criteria, History, Irrigation, Irrigation system, Irrigation practices, Agriculture.

The "state of the art" of drip irrigation in Israel is reviewed regarding both equipment and operational practices. Equipment available on the market is generally reliable and conforms to manufacturer's specifications of hydraulic properties. Filtering and clogging of small discharge orifices remains a problem under certain conditions. A standard head has been developed for connection to the main system incorporating filter, vacuum breaker, fertilizer applicator, pressure regulator, and automatic valves. Hydraulically or electrically actuated automatic valves are used either singly or for sequential operation. Many growers have reported excellent results with drip irrigation of orchards, truck crops, and flowers. The relative advantages of drip irrigation are especially pronounced where relatively saline water must be used under extremely arid conditions. Criteria and recommendations have yet to be determined regarding irrigation frequency and application amounts in relation to emitter spacing and discharge, and percent of wetted area for different crops, soil profile characteristics, climatic conditions, and water quality. Some consequences of improper operation may be under-irrigation, excessive restriction of the root zone, and excessive leaching of water and nutrients below the rooting depth.

74:03F-069
REVERSE FLUSHING TECHNIQUE FOR BI-WALL DRIP TUBING,
Rawlins, S.L.
United States Salinity Laboratory, Riverside, California.
Proceedings of the Second International Drip Irrigation Congress, pp. 209-211,
July 1974. 2 fig.

Descriptors: *Clogging, Irrigation, Agriculture, Irrigation systems.

Particles carried in the irrigation water first lodge in the inside orifices between the supply and emission chambers of biwall drip tubing. These can be effectively dislodged by briefly applying water at high pressure to the emission chamber. They can then be flushed from the supply chamber in the usual manner. Because the burst pressure of tubing varies inversly with its diameter, the small emission chamber can withstand considerably higher pressures than can the supply chamber. Results of tests using this technique are discussed.

74:03F-070
TRAVELING TRICKLE SYSTEM,
Rawlins, S.L., Hoffman, G.J., and Merrill, S.C.
United States Salinity Laboratory, Riverside, California.
Proceedings of the Second International Drip Irrigation Congress, pp. 184-187, July 1974.

Descriptors: Irrigation design, Cost comparisons, Cost analysis, Irrigation, Irrigation systems. Irrigation practices, Agriculture, Sprinkler irrigation.

Typical drip irrigation systems deliver frequent applications of small volumes of water by using a large number of small diameter orifices installed along tubes. The long lengths of tubes and large number of emitters required make drip irrigation costly for row crops. In addition, the small diameter of the orifices required to control water flow in such a system makes it susceptible to plugging and adds an additional filtration expense. We describe a traveling trickle system that circumvents both of these problems by controlling water application with a few large orifices moved along the row rather than with a large number of fixed location orifices. Results are presented from cost analyses for large-scale systems by converting standard center pivot sprinkler irrigation systems.

74:03F-071
USE OF GLYCEROPHOSPHATE FOR FERTILIZATION THROUGH TRICKLE IRRIGATION SYSTEMS,
Rolston, D.E., Ravschkolb, R.S., and Hoffman, D.L.
California University, Davis California.
Proceedings of the Second International Drip Irrigation Congress, pp. 416-421, July 1974. 3 fig, 9 ref.

Descriptors: *Fertilization, *Fertilizer, *Phosphorus, Irrigation practices, Irrigation systems, Irrigation, Agriculture.

There is little doubt after 60 years of scientific investigation with several sources of inorganic phosphate that phosphorus moves very little from point of contact with the soil. The greatest successes in measuring increased movement of phosphorus in the soil profile have occurred with organic forms of phosphorus. The development of new cultural management techniques such as trickle irrigation make the use of a water-soluble, non-corrosive, high analysis source of organic phosphorus an especially desirous material. A material with this capability would be of great value where trickle systems make it extremely difficult to achieve placement by mechanically injecting phosphorus below the soil surface. The movement and sorption of glycerol phosphate was studied in unsaturated soil columns during steady-state displacement of a fertilizer pulse. Fertilizer pulses equivalent to 90 kg/ha application rates were displaced at flow rates between 5 and 15 cm/day. Results demonstrate that glycerol phosphate is capable of being displaced to much greater depths than inorganic forms of phosphorus fertilizer. It is expected that glycerol phosphate can be applied through a trickle irrigation system and be distributed within the wetted root zone.

74:03F-072
SOIL MOISTURE DISTRIBUTION AND WETTING PATTERN FROM A POINT SOURCE,
Roth, R.L.
Arizona University, Yuma, Arizona.
Proceedings of the Second International Drip Irrigation Congress, pp. 246-251, July 1974. 4 fig.

Descriptors: *Wetting, *Water levels, *Flow rates, *Soil water, Irrigation, Irrigation systems, Agriculture.

Soil moisture distribution and wetting pattern tests were conducted using a point source on virgin desert sandy soil. The purpose of these studies was to characterize the extent of moisture movement and distribution within the wetted volume. The flow rates tested were approximately 3.8, 7.6, and 15.2 liters per hour (1, 2, and 4 gph) for durations of 1, 3, 6, 12, 24, and 48 hours. At the completion of each test, a pit was dug which exposed the maximum vertical diametral plane of the wetted volume. Measurements were made to define the maximum wetted area. Soil moisture measurements were made at each node point of a 15.2-centimeter (6-inch) grid imposed on the maximum wetted area. Soil cores were taken at 15.2-centimeter intervals along the line of maximum horizontal water movement. These cores were used to determine bulk density, soil texture, permeability, and moisture release characteristics. A complete soil profile description was also made of each test site. For the tests conducted the total volume of soil wetted was more a function of the amount of water applied than time of application. Maximum horizontal movement was greater than maximum vertical movement for volumes of water less than 190 liters (50 gallons). Greater maximum vertical movement occurred at volumes of water more than 190 liters. Water within the wetted volume was determined to be at tensions between 100-140 centimeters of water.

74:03F-073
COMPARISON OF IRRIGATION METHODS, ROOTSTOCKS, AND FERTILIZER ELEMENTS ON VALENCIA ORANGE TREES,
Roth, R.L., Rodney, D.R., and Gardner, B.R.
Arizona University, Yuma, Arizona.
Proceedings of the Second International Drip Irrigation Congress, pp. 103-108, July 1974.

Descriptors: *Sprinkler irrigation, *Surface irrigation, *Oranges, *Fertilization, *Fertilizers, Saline water Saline soil, Irrigation practices, Irrigation systems, Irrigation, Agriculture.

A 4-hectare (10-acre) block of 'Campbell' valencia orange trees planted in May 1971, was used to compare 5 irrigation methods, 2 types of rootstocks, and a phosphate and micronutrient variable. The irrigation methods were border, full-coverage sprinklers, limited-coverage sprinklers, basin, and trickle. Maximum tree growth, as measured by increase in trunk circumference, was achieved from the trickle and basin irrigation methods, even though these methods used approximately one-twentieth the water as compared to the normal border irrigation method. The full-coverage sprinkler method restricted tree growth due to salt injury of the leaves. Nitrate and salt concentrations in the root zone were mapped for each irrigation method. No observable effects of the fertilizer variables have been detected at this time.

74:03F-074
THE USE OF FOGGERS IN DRIP IRRIGATION,
Schade, R.O.
Perma Rain Irrigation, Inc., Lindsay, California.
Proceedings of the Second International Drip Irrigation Congress, pp. 129-130.

July 1974.

Descriptors: Crop response, Irrigation systems, Irrigation practices, Irrigation, Agriculture.

The rapid increase in drip irrigation in the United States has been accompanied by a large number of new products for its application. Most of this new equipment has been emitters of various types. These emitters are used to reduce the flow and to apply the water directly to the surface of the soil. In addition to emitters a device known as a fogger is also being widely used. The fogger as the name implies fogs or sprays the water into the air. The droplet size and output of each fogger ranges from 2 to 5 gallons per hour which is comparable to discharge rate of most emitters being used today. Foggers have been installed on an estimated 8,000 acres. This accounts for approximately 15% of the acreage being irrigated by drip irrigation. Foggers are being used to irrigate citrus, decidious fruit, grapes, nuts and ornamentals. The area of principal usage at the present time is in the San Joaquin Valley of California.

74:03F-075
TRICKLE IRRIGATION,
Shani, M.
Irrigation and Soil Field Service, Tel-Aviv, Israel.
Proceedings of the Second International Drip Irrigation Congress, pp. 91-96, July 1974.

Descriptors: Filtration, Fertilization, Irrigation systems, Irrigation practices, Irrigation, Agriculture.

Article presents advantages and disadvantages of trickle irrigation, types of emitters, filtration methods, and a discussion of fertilization techniques based on experience in Israel.

74:03F-076
DRIP IRRIGATION RESEARCH IN OREGON - A PROGRESS REPORT,
Shearer, M.N., Martin, L.W., Lombard, P.B., and Mellentin, W.M.
Oregon State University, Corvallis, Oregon.
Proceedings of the Second International Drip Irrigation Congress, pp.38-43, July 1974. 4 fig, 3 tab.

Descriptors: Crop response, Crop production, Sugarcane, Oregon, Irrigation system, Irrigation, Agriculture, Sprinkler irrigation, Filtration.

Drip irrigation research was initiated in Oregon in 1973. One year's results are reported on the following: (1) total yield, fruit size, water requirements, and mold incidence of cane fruit under drip and sprinkler irrigation, (2) total yield, fruit size, and water requirements of pears grown on low intake rate montmorillonite soils under drip and rill irrigation, (3) evaporation pan coefficients for scheduling drip irrigation, and (4) filtering requirements for irrigation water containing glacial silt and flour.

74:03F-077
DRIP VS. FURROW IRRIGATION TRIALS IN POTATO UNDER SUBTROPICAL CONDITIONS,
Singh, N.T., Grewal, S.S., and Josan, A.S.
Punjab Agricultural University, Ludhiana, India.
Proceedings of the Second International Drip Irrigation Congress, pp. 515-520, July 1974. 1 fig, 2 tab, 17 ref.

**Descriptors: *Potatoes, *Crop response, *Soil temperature, *Subtropic, Furrow irrigation, Irrigation systems, Irrigation practices, Irrigation, Agriculture.**

**The drip method of irrigation was compared with conventional furrow irrigation in field grown spring and autumn potatoes. Treatments included irrigations at 0.25, 0.50, and 0.75 bar soil moisture tension at 10 cm depth and drip irrigation. As an average of six crops, for equal amounts of water used drip irrigation gave 60 q/ha or 31% higher yield than irrigation at 0.25 bar soil moisture tension. Irrigation at 0.50 and 0.75 bar tension yielded significantly lower than these treatments. Wetter soil moisture regimes lowered the maximum soil temperature at 10 cm depth by 1 to 3.5°C thereby bringing it closer to the optimum required by the crop. Effect of soil moisture on soil temperature and soil strength was isolated using organic mulches. Soil temperature appeared to be a critical factor in improving yield and quality of potatoes. Drip irrigation promises a more suitable soil moisture and soil temperature regime for potato cultivation in the subtropics.**

74:03F-078
EDAPHIC MICRO-TUBULAR CONTINUOUS FLOW IRRIGATION IN CANADA,
Stevenson, D.S. and Tait, R.S.
Canadian Department of Agriculture, Summerland, B.C.
Proceedings of the Second International Drip Irrigation Congress, pp. 86-90, July 1974. 3 fig, 4 tab.

Descriptors: Soil water movement, Canada, Irrigation systems, Irrigation, Agriculture.

A soil's ability to transfer water horizontally relative to vertical drainage is its most important characteristic in trickle irrigation. Water applied to a soil at a single point will move laterally and vertically. The shape of the resulting half sphere will depend upon the ratio of saturated conductivity to unsaturated conductivity of any particular soil. The limit to horizontal movement before drainage becomes excessive determines that area that we can expect to irrigate with one dripper. Rooting depth of the crop imposes a limit to the area over which water will spread before an excess of it becomes drainage. Evapotranspiration (ET) over the area so defined thus determines the continuous flow from the dripper. Areas and ET are easily equated to provide dripper flows in g.p.h. The areas provide the dripper spacing for uniform irrigation. Micro-tubing of varying sizes and lengths as emitters provides flow control at the emitters for both level and sloping land. Seasonal changes in irrigation requirements (ET) are satisfied by alterations in line pressures as needed.

74:03F-079
MOISTURE PROFILES AND SALINIZATION OF SOILS UNDER DRIP IRRIGATION IN THE REPUBLIC OF SOUTH AFRICA,
Streutker, A.
Department of Agricultural Technical Services, Pretoria, South Africa.
Proceedings of the Second International Drip Irrigation Congress, pp. 258-263, July 1974. 4 tab.

Descriptors: *Saline soil, *Moisture content, *Crop production, *Flow rates, *Cotton, *Potatoes, *Tomatoes, Irrigation practices, Irrigation systems, Irrigation, Agriculture.

Soil moisture profiles, salinization of soils, water use, and production of cotton, potatoes and tomatoes are measured on experimental plots on four soils, from sand to clay, with three different dripper spacings, and three different drip intensities. Simultaneously, soil moisture profiles and salinization are measured on different soils under citrus-trees, peach-trees and vineyards with commercial drip irrigation systems under different climates.

74:03F-080
AFFORESTATION WITH SALINE WATER IN ABU DHABI,
Tahnoon, S. and Aljibury, F.K.
Minister of Agriculture, Abu Dhabi.
Proceedings of the Second International Drip Irrigation Congress, pp. 370-371, July 1974.

Descriptors: *Forestry, *Saline water, Irrigation systems, Irrigation, Agriculture.

The government of the country of Abu Dhabi is trying to make the desert bloom under adverse soil, wind, and water conditions.

74:03F-081
EFFECTS OF LOCALIZED PHOSPHATE TREATMENTS AND SOLUTION pH ON THE GROWTH AND FUNCTION OF APPLE ROOTS,
Taylor, B.K. and Goubran, F.G.
Scoresby Horticultural Research Station, Ferntree Gully, Australia.
Proceedings of the Second International Drip Irrigation Congress, pp. 395-399, July 1974. 4 tab.

Descriptors: *Phosphates, *Crop response, *Apples, *Root development, Nutrients, Irrigation systems, Irrigation, Agriculture.

Following the introduction of trickle irrigation to orchards, interest has risen in the possibility of feeding nutrients into such systems on a regular basis. Use of phosphatic fertilizer in this way, however, could pose a problem in that a highly localized source of P would be available to only a small portion of the root system of the tree. Movement of P away from the trickle outlet would be restricted in most orchard soils by fixation processes. The influence of localized applications of phosphate on the growth and function of apple roots at two pH levels is reported.

74:03F-082
SOME RESULTS OF A FIELD SURVEY OF DRIP IRRIGATION SYSTEMS IN THE REPUBLIC OF SOUTH AFRICA,
Uys, W.J.
Department of Agricultural Technical Services, Pretoria, South Africa.
Proceedings of the Second International Drip Irrigation Congress, pp. 65-70, July 1974. 4 tab.

Descriptors: *Clogging, Flow rates, *Surveys, Irrigation, Irrigation systems, Agriculture.

An extensive survey was conducted in the Republic of South Africa on existing drip irrigation systems to evaluate drip irrigation systems under a variety of climatic, soil, crop and management conditions. The purpose of the survey is to identify specific problems of practical farming conditions and to identify specific problems of design, operation, and management from which future extension and research programs can be formulated.

74:03F-083
DISINFECTION OF SOIL STRIPS THROUGH THE DRIP IRRIGATION SYSTEM,

Uzrad, M. and Goldberg, S.D.
The Hebrew University of Jerusalem, Rehovat, Israel.
Proceedings of the Second International Drip Irrigation Congress, pp. 137-141, July 1974. 3 tab.

Descriptors: *Disinfection, Management, Crop production, Irrigation systems, Irrigation, Agriculture.

Seasonal crops (vegetables) are often grown on a limited area in the Arava agricultural plots thus causing contamination. Manure of unknown origin increases the rate of contamination. After several seasons of cultivation, there is a marked decrease in the level of the agricultural production. It is customary to disinfect soils by means of methyl bromide. Row crops in the Arava desert are irrigated by the drip system, thus the cultivation, fertilization, and irrigation is restricted to the cultivated strip. An experiment was conducted to apply the disinfectant only to the cultivated strip through the drip system. Hot gaseous methyl bromide was applied through the drip laterals and through the drippers which were covered by plastic mulch. The treated areas yielded crops three times higher than in the control plot.

74:03F-084
HYDRAULICS OF SINGLE-CHAMBER VS. DUAL-CHAMBER TUBING,
Vaziri, C.M.
Hawaiian Agronomics, Inc., Honolulu, Hawaii.
Proceedings of the Second International Drip Irrigation Congress, pp. 293-298, July1974. 2 tab.

Descriptors: *Hydraulic design, *Hydraulic properties, *Hydraulics, *Irrigation design, Irrigation, system, Irrigation, Agriculture.

The basic hydraulic relationship of pressure, orifice diameter, coefficient of discharge, and the friction loss along a tube is a necessity before one can design an adequate drip or subsurface irrigation system. There are several types of tubing and emitters available. But the most unique difference hydraulically is the single chamber tubing versus a dual chamber tubing. The single chamber tube is found to provide an acceptable range of orifice flow uniformity from the head of tubing to the end for approximately 300' of length. Beyond this reach the friction loss in the 1/2" polyethylene tubing is excessive and causes a reduction in the orifice flow rate. The flow rate through each plastic orifice is proportional to the square root of the pressure inside the tubing at the orifice point. The other type of tubing that has been experimented with is dual chamber tubing. One chamber is for the conveyance. This in turn is connected to the outside chamber (the distribution tube) and water is emitted to the outside through desired orifice spacing, depending on soil types and plantings. Equations are developed to describe the flow pattern for dual chamber tubing and the relationship between the inner and outer chamber. The effect of orifice diameters and orifice spacing on the outer chamber pressure is discussed.

74:03F-085
LINEARIZED MOISTURE FLOW SOLUTIONS FOR POINT, LINE, AND STRIP SOURCES,
Warrick, A.W. and Lomen, D.O.
Arizona University, Tucson, Arizona.
Proceedings of the Second International Drip Irrigation Congress, pp. 228-233, July 1974. 3 fig, 1 tab, 12 ref.

Descriptors: *Soil water movement, Mathematical studies, Irrigation system, Irrigation, Agriculture.

Solutions and numerical results are given for the time-dependent, linearized moisture flow equation for point, line, and strip sources. The linear form is attained by assuming an unsaturated hydraulic conductivity of the form $K = k_o$ exp (alpha h) with $K_o$ and alpha constants and with h the pressure head. In addition, the derivative of K with respect to the volumetric water content is taken as a constant. Numerical results include; (1) spatial distribution of the matric flux potential for 6 times including a comparison of 2 flow rates for a point source; (2) pressure head distribution near a single point source under cyclic conditions; (3) pressure head distribution for 2 point sources under cyclic conditions, and (4) moisture distribution patterns near line and strip sources. The major advantage of using the linearized forms is that solutions for simplified geometries may be superimposed both in time and space to simulate complex geometries and inputs of water. The major disadvantage of the non-linear nature of the soil-hydraulic functions is lost. For cyclic moisture regimes at a high frequency, it is assumed the water content fluctuation of any point will be relatively small and the linearizing assumptions are realistic.

74:03F-086
MOBILE DRIP IRRIGATION SYSTEMS,
Wilke, O.C.
Texas Agricultural Experiment Station, Lubbock, Texas.
Proceedings of the Second International Drip Irrigation Congress, pp. 188-192, July 1974. 5 fig.

Descriptors: Irrigation design, Irrigation operation and maintenance, Irrigation practices, Irrigation, Agriculture.

A tractor-mounted device for moving drip irrigation laterals is described. Time periods required to load, move and unload laterals are presented. Several drip irrigation trail lines were attached to a pivot sprinkler system. The design and performance of the system are discussed.

74:03F-087
SEED GERMINATION RESPONSE TO SUBSURFACE IRRIGATION DEPTH,
Willardson, L.S.
Agricultural Research Service, Brawley, California.
Proceedings of the Second International Drip Irrigation Congress, pp. 178-182, July 1974. 4 fig, 2 ref.

Descriptors: *Subsurface irrigation, *Cotton, *Alfalfa, *Germination, Crop response, Irrigation practices, Irrigation, Agriculture.

A line source subsurface irrigation system was installed at 0, 2.54, 5.08, 10.16, and 20.32 cm depths in a sandy silt soil. The E.C. of the soil varied between 10.4 and 16.2 mmhos per cm. Cotton and alfalfa were used to determine the effect of depth of placement of the seeds and water source on germination.

74:03F-088
CANTALOUPE RESPONSE TO DRIP IRRIGATION,
Willardson, L.S., Bohn, G.W., and Huber, M.J.
Agriculture Research Service, Brawley, California.
Proceedings of the Second International Drip Irrigation Congress, pp. 474-479, July 1974. 3 tab.

Descriptors: *Root distribution, *Crop response, *Furrow irrigation, Irrigation systems, Irrigation practices, Irrigation, Agriculture.

Changes in rooting pattern may change nutrition and plant response, and thus alter desirable characteristics of plants. Five experiments conducted included nine cantaloupe cultivars grown on silty clay loam with drip and furrow irrigation systems. The different irrigation management practices followed have resulted in variable plant responses.

74:03F-089
CONTROL OF WATER BY DRIP IRRIGATION FOR ALFALFA SEED PRODUCTION,
Willardson, L.S., Hageman, R., and Marsh, A.W.
Agriculture Research Service, Brawley, California.
Proceedings of the Second International Drip Irrigation Congress, pp. 172-177, July 1974. 2 tab, 3 fig.

Descriptors: *Alfalfa, *Seeds, Crop response, Irrigation systems, Irrigation practices, Irrigation, Agriculture.

Drip irrigation controlled soil water tension treatments in an alfalfa seed production experiment resulted in a 4-fold yield difference between the best and poorest treatments. The experiment had 6 replications of 4 treatments and has been conducted for 2 years. Yield of forage as well as seed yields were determined.

74:03F-090
SALINITY SENSOR CONTROL OF DRIP IRRIGATION WATER APPLICATION,
Willardson, L.S. and Oster, J.D.
Agriculture Research Service, Brawley, California.
Proceedings of the Second International Drip Irrigation Congress, pp. 335-340, July 1974. 3 fig, 1 tab, 1 ref.

Descriptors: *Salinity, *Saline soil, Crop response, Irrigation practices, Irrigation systems, Irrigation, Agriculture.

In-situ salinity sensors were used to control water application by drip irrigation to maintain a constant soil salinity. Milo was grown on small field plots instrumented with salinity sensors to evaluate the effect of depth of placement and initial soil salinity on plant growth and water control. Water application was fully controlled by the sensors. Response time was short enough to encourage practical use.

74:03F-091
AN INVESTIGATION INTO THE POTENTIAL USES OF TRICKLE IRRIGATION FOR DESERT RECLAMATION AND FODDER PRODUCTION IN THE EMIRATE OF ABU DHABI,
Willens, A.F. and Willens, G.A.
Agricultural Planning Associates, Ltd. London, England.
Proceedings of the Second International Drip Irrigation Congress, pp. 288-293, July 1974. 4 tab, 4 ref.

Descriptors: Crop response, Land reclamation, Deserts, Irrigation systems, Irrigation, Agriculture.

An initial investigation into the possible uses of trickle irrigation to establish a range of plant species which could be potentially useful as fodder is described. The use of trickle irrigation for fodder tree production shows considerable potential and appears economically viable within the present social context of Abu Dhabi.

74:03F-092
CHANGES IN ROOT PATTERNS OF PEACH TREES UNDER TRICKLE IRRIGATION,

Willoughby, P. and Cockroft, B.
Department of Agriculture, Victoria, Australia.
Proceedings of the Second International Drip Irrigation Congress, pp. 439-442, July 1974. 3 tab.

Descriptors: *Peaches, *Root development, *Root distribution, *Root systems, Crop response, Irrigation effects, Irrigation systems, Irrigation, Agriculture.

With fully mature peach trees, which before the installation of a trickle system had a uniformly distributed root system through the whole orchard area, the change to trickle produced a remarkable adaption by the tree. A whole new root system was developed in a few months, and the trees continued to produce heavy crops of fruit.

74:03F-093
USE OF DRIP IRRIGATION IN GERMANY,
Wolff, P.
Kassel University, Germany.
Proceedings of the Second International Drip Irrigation Congress, pp. 71-76, July 1974.

Descriptors: Sprinkler irrigation, Irrigation systems, Irrigation, Agriculture.

Irrigation methods similar to drip irrigation have been used in Germany for many years, and more horticulturalists are changing from overhead irrigation to drip irrigation. The reasons for changing irrigation methods were investigated by the author and his coworkers. It was found that the horticulturalists are changing methods because of increasing labor costs and an increasing demand for high quality products.

74:03F-094
DRIP IRRIGATION IN CITRUS ORCHARDS,
Yagev, E. and Choresh, Y.
Ministry of Agriculture, Israel.
Proceedings of the Second International Drip Irrigation Congress, pp. 456-461, July 1974. 2 fig, 7 tab.

Descriptors: *Oranges, *Crop response, Root development, Salinity, Saline soil, Irrigation systems, Irrigation, Agriculture.

In a Valencia orange grove grafted onto sour orange root stock, drip irrigation treatments of one and two laterals per row of trees at semi-weekly and bi-weekly intervals was compared to the standard treatment of sprinkler irrigation. The water application to all treatments was based on identical daily rates. The factors checked were salt accumulation and moisture distribution pattern in the soil profile, root development, mineral content of leaves, weight of yield and number of fruit per tree, and fruit quality. There was no difference in yield and fruit quality between the treatments checked. The average salt accumulation in the soil was less with the drip irrigation treatments than with the sprinkler irrigation. The soil moisture tension below the drip lateral was low all the time and there is reason to believe that there is a loss of water below the root zone. There was no significant difference in root development between all the treatments.

74:03F-095
STEADY INFILTRATION FROM LINE SOURCES BURIED IN SOIL,
Thomas, A.W., Kruse, E.G., and Duke, H.R.
United States Department of Agriculture, Watkinsville, Georgia.

Transactions of the American Society of Agricultural Engineers, Vol. 17, No. 1, p 125-129 & 133, January-February 1974. 7 fig, 6 ref.

Descriptors: *Soil water movement, *Subsurface irrigation, *Infiltration, *Mathematical studies, Mathematical modeling, Irrigation systems, Irrigation, Agriculture.

Paper presents the results of a study of steady infiltration from a distribution of buried line sources which lie in a horizontal plane and are parallel and equally spaced. The sources simulate subsurface irrigation laterals. An analytical solution is made possible by the use of a quasilinear form of the differential flux equation and an exponential relationship between hydraulic conductivity and capillary potential of the soil modeled. The objective of the paper is to develop the analytical solution and compare the computed distributions of capillary potential for normal field lateral spacings and depths with those computed by more complex methods.

74:03F-096
HIGH RATE SPRINKLING OF A LOW INTAKE SOIL,
Willardson, L.S., Ertsgaard, B.L., Ehlig, C.F., and MacKenzie, A.J.
United States Department of Agriculture, Brawley, California.
Transactions of the American Society of Agricultural Engineers, Vol. 17, No. 2, p 280-281, March-April 1974. 2 fig, 1 tab.

Descriptors: *Sprinkler irrigation, Irrigation practices, Irrigation operation and management, Irrigation effects, Frequency, Puddling, Soil management, Soil properties, Irrigation, Agriculture.

Water can be applied to low intake rate soils by sprinkling at high average application rates if water is applied intermittently and the average application rate does not exceed the average instantaneous intake rate during the interval of operation. Soil crusts formed on the soil surface when the soil dried, but these crusts did not interfere with plant growth. Greater total amounts of water can be applied without causing ponding and loss of soil surface structure by the use of short sprinkling intervals and by applying smaller amounts of water per day. For equal amounts of applied water, short duration - high frequency applications caused less loss of soil surface structure than long duration - low frequency applications.

74:03F-097
CHAMBER METHOD OF SUBSURFACE AND DRIP IRRIGATION,
Pira, E.S. and Purohit, K.S.
Massachusetts University, Amherst, Food and Agricultural Engineering Departmen.
Transactions of the American Society of Agricultural Engineers, Vol. 17, No. 2, p282-285, March-April 1974. 6 fig, 18 ref.

Descriptors:*Design criteria, *Irrigation design, *Subsurface irrigation, *Head loss, Irrigation methods, Flow rates, Irrigation, Agriculture.

By varying cross sectional area and length of the low pressure distribution line (chamber), uniform discharge rates can be produced through emitters. Discharge rates can be changed by adjusting chamber pressure. "Quick-fill" is necessary to make the system practical. In other words, the chamber must be charged with water before good operation begins. Field installation in an apple orchard is discussed.

74:03F-098
ALTERNATE-FURROW IRRIGATION OF FINE TEXTURED SOILS,

Musick, J.T. and Dusek, D.A.
United States Department of Agriculture, Bushland, Texas, Southwestern Great Plains Research Center.
Transactions of the American Society of Agricultural Engineers, Vol. 17, No. 2, p 289-294, March-April 1974. 10 fig, 1 tab, 8 ref.

Descriptors: *Furrow irrigation, *Furrow systems, Irrigation effects, Irrigation efficiency, Irrigation practices, Furrows, Crop response, Sugarbeets, Grain sorghum, Potatoes, Soil salinity, Infiltration rates, Irrigation, Agriculture.

Alternate-furrow irrigation of bed-furrow spacings ranging from 30 to 40 inches were evaluated for irrigating slowly permeable Pullman soils. Alternate-furrow irrigation had little effect on water intake and yields on Pullman silty clay loam but significantly reduced both intake and yields of sugarbeets and grain sorghum on Pullman clay loam. The reduction in water intake and yields was concentrated on the lower one-fourth to one-half of the field plots depending primarily on the irrigated furrow spacing and length of run. Lateral wetting extended from the irrigated furrow into the adjacent nonirrigated furrow past midfield under all conditions evaluated. Alternate-furrow irrigation of bed-furrow spacings exceeding 30 inches is not recommended on slowly permeable clay loam soils. Although alternate furrow irrigation significantly reduced the size of irrigation, the concentration of this effect on the lower part of a field and associated yield reductions limits the usefulness of the practice for more efficient management and use of water.

74:03F-099
IRRIGATION TIMING BY THE STRESS DAY INDEX METHOD,
Hiler, E.A., Howell, T.A., Lewis, R.B., and Boos, R.P.
Texas A&M University, College Station, Agricultural Engineering Department.
Transactions of the American Society of Agricultural Engineers, Vol. 17, No. 3, p 393-398, May-June 1974. 2 fig, 8 tab, 28 ref.

Descriptors: *Stress, *Stress analysis, Irrigation practices, Crop production, Optimization, Water conservation, Water requirements, Irrigation, Agriculture.

A potentially useful concept for optimizing irrigation timing is the stress day index (SDI). The purposes of this paper are to briefly define SDI and its components, to illustrate through examples how this approach can be utilized for timing irrigations, and to present experimental findings related to use of SDI. The SDI concept is formulated as the product of a crop susceptibility factor (CS) and a stress day factor (SD). Values of CS depend on species and stage of development and indicate the plant's susceptibility to a given water deficit at different growth stages. A method for determining CS is given along with quantitative values for various irrigated crops. Irrigation timing is accomplished with the SDI approach by irrigating when the daily SDI (daily SD x CS for the appropriate growth stage) reaches some predetermined critical value. Basically, the water deficit indicator(SD) is weighted according to crop sensitivities at different growth stages so that reduced water deficit occurs during critical periods.

74:03F-100
WATERHAMMER CONSIDERATIONS FOR PVC PIPELINE IN IRRIGATION SYSTEMS,
Seipt, W.R.
Certain-teed-Products Corporation, Valley Forge, Pennsylvania.
Transactions of the American Society of Agricultural Engineers, Vol. 17, No. 3, p 417-423, May-June 1974. 6 fig, 5 tab, 26 ref.

Descriptors: *Waterhammer, Hydraulic conduits, Hydraulic design, Hydraulic equipment, Hydraulic structures, Irrigation design, Flow Characteristics,

Agriculture, Irrigation.
Waterhammer pressure develops whenever flow is changed. Flow changes occur by operating valves, by starting or stopping pumps, or by sudden release of entrapped air. Its intensity depends upon the rate of change. On occasion, it damages piping. Waterhammer can be contained by: adequate design; proper installation and responsible use.

74:03F-101
EVERY-OTHER FURROW IRRIGATION OF CORN,
Fischbach, P.E. and Mulliner, H.R.
Nebraska University, Lincoln, Agricultural Engineering Department.
Transactions of the American Society of Agricultural Engineers, Vol. 17, No. 3, p 426-428, May-June 1974. 4 tab, 9 ref.

Descriptors: *Irrigation practices, Irrigation effects, Irrigation efficiency, Corn, Furrow irrigation, Surface irrigation, Irrigation, Agriculture.

Every-other furrow irrigation was compared with every furrow irrigation on several soil types in Nebraska under various rainfall conditions. Analysis of the data shows no significant differences at the 5 percent level in corn grain yields on any soil texture when comparing every-other furrow with every furrow irrigation using 2 1/3 to 12-hr. irrigation sets. Further analysis of the data shows that the irrigation water moves laterally from the irrigated furrow to the adjacent dry furrow to a depth of 3 feet even with a 2 1/3-hr. irrigation set. Therefore, both manually and automated irrigation systems can be designed for every-other furrow irrigation.

74:03F-102
DRIP IRRIGATION DESIGN BASED ON UNIFORMITY,
Wu, and Gitlin, H.M.
Hawaii University, Honolulu, Department of Agricultural Engineering.
Transactions of the American Society of Agricultural Engineers, Vol. 17, No. 3, p 429-432, May-June 1974. 4 fig, 5 ref.

Descriptors: *Uniformity coefficient, *Irrigation design, Irrigation systems, Irrigation, Agriculture.

The paper presents a general shape of the energy gradient line which can be applied to estimate distribution and variation of emitter discharge along the lateral. A design chart is presented for determining an acceptable combination of lateral lengths and inlet pressure of a drip irrigation system. The chart helps in selecting a drip irrigation line based on a desirable or acceptable uniformity coefficient. The designer can try different combinations and length in order to obtain a design which is acceptable.

74:03F-103
SPRINKLER IRRIGATION DESIGN CRITERIA FOR SUGAR BEETS,
Finken, D.W., Steele, J.C., and Fischbach, P.E.
Nebraska University, Scottsbluff, District Extension Irrigation Engineer, Panhandle Station.
Transactions of the American Society of Agricultural Engineers, Vol. 17, No. 5, p 889-891, September-October 1974. 5 tab, 7 ref.

Descriptors: *Sprinkler irrigation, *Irrigation design, Irrigation practices, Design criteria, Sugarbeets, Consumptive use, Nebraska, Crop response.

A solid set sprinkler system was used to simulate center pivot sprinklers in a search for the smallest design capacity which would not reduce yields of irrigated sugar beets. The peak daily consumptive use of sugar beets in western Nebraska is about 0.33 in. per day. A system with the capacity to supply this amount to the crop would need a capacity in excess of 0.33 in. per day to allow for water losses. The results indicate that systems that can apply 0.20 in per day, without allowing for water losses, are sufficient to produce sugar beets in western Nebraska without incurring a reduction in yield.

74:03F-104
TRICKLE IRRIGATION LATERAL DESIGN,
Howell, T.A. and Hiler E.A.
Texas A&M University, College Station, Agricultural Engineering Department.
Transactions of the American Society of Agricultural Engineers, Vol. 17, No. 5, p 902-907, September-October 1974. 5 fig, 2 tab.

Descriptors: *Irrigation design, *Hydraulics design, *Hydraulic properties, *Computer programs, Irrigation systems, Irrigation, Agriculture, Design.

A design method for determining the pressure loss and emitter flow ratio for trickle irrigation laterals is presented. The design method is based upon known principles of fluid mechanics. A computer program was written to determine the lateral pressure loss and emitter flow ratio at a given design length as a fuction of pipe size, tree spacing, number of emitters per tree, emitter spacing, downstream lateral pressure, and lateral slope. For a given set of design inputs, the program can be used to determine if the given pipe size will be adequate to limit the pressure loss and flow variation along the lateral to limits acceptable for the design lateral length.

74:03F-105
THE EFFECT OF SOIL WATER SUPPLY ON CORN FERTILIZER RESPONSE,
Olson, T.C. and Onstad, C.A.
United States Department of Agriculture, Agricultural Research Service, Morris, Minnesota.
Transactions of the American Society of Agricultural Engineers, Vol. 17, No. 5, p 914-916, September-October 1974. 5 tab, 10 ref.

Descriptors: *Crop response, *Corn, *Soil water, *Fertilization, Rainfall, Crop production, Statistics, Agriculture, Agronomic crops, Moisture stress, Moisture availability, Moisture content.

The study reported was designed to determine the possibility of estimating the optimum amount of fertilizer needed for greatest efficiency when the amount of water stored in the soil profile at planting time is known. Conversely, would increasing stored water increase the efficiency of fertilizer? Responses to applied fertilizer under different levels of stored water at planting and different patterns of rainfall were studied to identify the types of interactions between water stress and fertility response by corn. Corn grain yields for six treatments are reported for each year. Significant differences as indicated by LSD are shown on an individual year basis. Annual average yields of main treatments illustrate the influence of stored water. The combined analysis of varience indicated highly significant differences in yield among years but no significant difference in overall average yields among main treatments or between fertility levels. The year x main treatment, and the year x fertility-level interactions were both highly significant ($p= 0.01$) and the main-treatment x fertility level x year interaction was significant at the 0.05 level.

74:03F-106
TRICKLE IRRIGATION DESIGN PARAMETERS,
Keller, J. and Karmelli, D.

Utah State University, Logan, Agricultural and Irrigation Engineering Department.
Transactions of the American Society of Agricultural Engineers, Vol. 17, No. 4, p 678-684, July-August 1974. 4 fig, 1 tab, 12 ref.

Descriptors: *Design criteria, *Irrigation design, Design flow, Flow characteristics, Irrigation, Agriculture.

Paper consists of basic definition, objectives of trickle, advantages and disadvantages. Formulas for computation of irrigation depth and interval, flow rates through emitters, system capacity, flow characteristics of various emitters, and emission uniformity (EU) are all presented. Lateral and manifold design are presented along with an example of system layout with complete design figures.

74:03F-107

### INSTALLATION CHECKS ON 4-INCH (102 MM) CORRUGATED POLYETHYLENE DRAIN TUBING,

McCandless, D.E., Jr.
Presented at 1974 Winter Meeting of the American Society of Agricultural Engineers, December 10-13, 1974. Chicago, Illinois. 8 tab, 3 ref.

Descriptors: *Plastic pipes, Pipelines, Construction, Drainage, Drainage engineering, Drainage practices.

Results of 54 installation checks on a 4-inch (102 mm) corrugated polyethylene drain tubing in 4 Northeastern states are reported. Checks were made by Soil Conservation Service personnel with the assistance of farmers, contractors, and manufacturers' representatives. Tubing installed in gravel soil sites generally had deflections 2 to 5 percent higher than those in clay or sandy soils. Tubing installed in sandy soils had the least deflection and commonly ranged from 13 to 20 percent. Tubing installed in trenches 4 to 5 feet (1.2 to 5 m) deep in sandy soils was doing as well or better than tubing installed at lesser depths. Subsurface drains in the Northeast are commonly installed in trenches 2 1/2 to 4 feet (0.8 to 1.2 m) deep. With 14 percent of the sites being classified as unsatisfactory, it is obvious that in many areas of the Northeast there is a need for a training and installation program on good installation procedures for SCS personnel, contractors, and farmers.

74:03F-108

### ELONGATION CHARACTERISTICS OF CORRUGATED PLASTIC TUBING,

Schwab, G.O. and Brehm, R.D.
Ohio State University, Columbus.
Presented at 1974 Winter Meeting of the American Society of Agricultural Engineers, December 10-13, 1974. Chicago, Illinois. 5 fig, 6 ref.

Descriptors: *Plastic pipes, Plastic deformation, Temperature, Pipelines, Construction.

Elongation (stretch) of circular corrugated plastic tubing decreased parallel plate stiffness at 5% deflection about 1.6%, 2.3%, and 0.4% for each one percent elongation of 76 mm (3-in), 102 mm (4-in), and 152 mm (6-in) diameter tubing, respectively. Four brands of tubing were included in the tests. Stiffness of 203 mm (8-in) diameter tubing consistently (4 brands) increased up to 5% elongation with only a small decrease at 10%. In other tests the elongation of three brands of 102 mm tubing varied from about 2 to 6% at 23°C (standard test temperature) and from 9 to 18% at 70°C. For all three brands tested, elongation varied linearly with temperature. Spiral corrugations showed less elongation than circular corrugated tubing. Elongation of corrugated tubing in the field as installed with several trenching machines varied from zero to 4.5% with an average of 2.1%. Although tubing temperature was high (35 to 52°C), temperature did not appear to be a major cause of stretching. Frictional drag and other effects as the tubing passed through the machine caused most of the stretching. The study showed that elongation is not a serious (up to 5%) problem unless the contractor is careless of intentionally stretches the tubing.

74:03F-109
FUNDAMENTALS OF PROGRAMMED SOIL MOISTURE DEPLETION,
Fonken, D.W. and Fischbach, P.E.
Nebraska University, Panhandle Station, Scottsbluff.
Presented at 1974 Winter Meeting of the American Society of Agricultural Engineers, December 10-13, 1974. Chicago, Illinois. 4 fig, 11 ref.

Descriptors: *Scheduling, Soil moisture, Water utilization, Irrigation, Irrigation practices, Irrigation operation and management, Energy.

Programmed soil moisture depletion is an irrigation scheduling policy for achieving improved water use efficiency and energy savings. It requires medium or fine textured soils, irrigation hardware that can apply small controlled amounts of water, a climate and/or irrigation supply which can provide off-season rainfall and irrigation, and a relatively high level of irrigation management. It is recommended as a technique to reduce peak season irrigation requirements by utilizing previously wasted rainfall and off-season irrigation capability.

74:03F-110
ANHYDROUS AMMONIA APPLICATION IN IRRIGATION WATER VS. MECHANICAL AND ITS EFFECT ON CORN YIELDS,
Mulliner, H.R. and Frand, K.D.
Nebraska University, South Central Station, Clay Center, Department of Agricultural Engineering.
Presented at 1974 Winter Meeting of the American Society of Agricultural Engineers, December 10-13, 1974. Chicago, Illinois. 4 tab.

Descriptors: *Nitrogen, *Nitrogen compounds, *Corn, Fertilization, Fertilizers, Irrigation practices, Irrigation water, Irrigation.

Application of anhydrous ammonia in surface irrigation distribution systems requires top level management. From an energy standpoint, it is more effective because optimum yields can usually be obtained with less nitrogen, and the energy for mechanical application is saved. In the manufacturing process, energy is required to convert anhydrous ammonia to ammonium nitrate and urea; thus, the ability to utilize anhydrous ammonia directly in surface irrigation systems is an additional savings of energy. Salts in the irrigation water presented no problem of encrusting inside the distribution system (aluminum gated pipe) when the inhibitor sodium polyphosphate was used. Irrigation water will carry from 50 to 110 ppm anhydrous ammonia before it is lost into the atmosphere. Keeping within these limitations is necessary for efficient application. Optimum grain yields were obtained with the application of 120 pounds of nitrogen. In 1972, grain yields were essentially the same whether anhydrous ammonia was applied in the irrigation water or applied mechanically. In 1973, water applied anhydrous ammonia gave significantly better yields than mechanically applied ammonia.

74:03F-111
UPWARD WATER MOVEMENT ON FIELD CORES,
Wells, L.G.
Kentucky University, Lexington, Department of Agricultural Engineering.

Presented at 1974 Winter Meeting of the American Society of Agricultural Engineers, December 10-13, 1974. Chicago, Illinois. 15 fig, 2 tab, 25 ref.

Descriptors: *Subsurface irrigation, *Soil water movement, Irrigation, Irrigation design, Irrigation systems, Hydraulic conductivity, Model studies, Soil properties.

Subirrigation experiments were conducted under various initial and boundary conditions using large, undisturbed soil cores representing two field soils. Water flow volumes and pressure potential distirbutions were monitored continuously during each test. The desorption soil water characteristic was determined for both soils using pressure plates. The effective saturated hydraulic conductivity was determined for each core used in the experiments. The relationships between hydraulic conductivity and pressure potential, K(k), was determined for each soil type from transient pressure potential measurements during a drainage event. An approximate model was developed to describe vertical water movement during subirrigation. The model assumed that the water rises uniformly in the profile, making no provision for water movement in advance of the water table. The model is capable of considering profile stratification. Also the one dimensional h-form of the Richards equation was solved numerically for conditions corresponding to those imposed during the experiment.

74:03F-112
MODELING INFILTRATION AND REDISTRIBUTION OF SOIL WATER DURING INTERMITTENT APPLICATIONS,
James, L.G. and Larson, C.L.
Minnesota University, St. Paul, Department of Agricultural Engineering.
Presented at 1974 Winter Meeting of the American Society of Agricultural Engineers, December 10-13, 1974. Chicago, Illinois. 17 fig, 2 tab, 22 ref.

Descriptors: *Model studies, *Computer models, *Infiltration, Soil water, Soil water movement, Wetting, Infiltration rates.

A model based on equations that use measured physical parameters to represent the infiltration and redistribution of soil water during intermittent water applications with reasonable simplicity and accuracy is needed. A computer model combining the work of other researchers was developed to fulfill this need. Inputs required by the model include the soils' saturated conductivity and moisture content, its approximate conductivity-moisture content and conductivity-capillary pressure relationships, its initial moisture content as well as the distance from the soils' surface to its lower boundary. Model output includes the depths and moisture contents of both primary and secondary wetting fronts, the rates of infiltration, surface and subsurface supply as well as the total volume of water applied, infiltrated and supplied to surface and subsurface runoff. Experimental laboratory data for a graded silica sand was collected and compared to model predictions. Results presented indicate that the model does an excellent job of predicting the volume of water stored in the soil zone as well as the times when surface and subsurface runoff begin. It also gives excellent predictions of infiltration rate and surface and subsurface runoff supply rates when the application rate is less than or equal to the soils' saturated conductivity.

74:03F-113
OPTIMIZATION OF WATER USE EFFICIENCY UNDER HIGH FREQUENCY IRRIGATION: II SYSTEM SIMULATION AND DYNAMIC PROGRAMMING,
Howell, T.A., Hiler, E.A., and Reddell, D.L.
Texas A&M University, College Station, Agricultural Engineering Department.
Presented at 1974 Winter Meeting of the American Society of Agricultural Engineers, December 10-13, 1974. Chicago, Illinois. 3 fig, 5 tab, 17 ref.

Descriptors: *Optimization, Dynamic programming, Simulated rainfall, Simulation analysis, Monte Carlo method.

An environmental simulation model (temperatrue, rainfall, and potential evaporation) was developed for Temple, Texas. Using Monte Carlo techniques, daily environmental data could be simulated for input to the soil water balance model. The simulation results adequately represented the stochastic serial-correlation of these variables. Stochastic dynamic programming was used to maximize yield, subject to water availability constraints. These results showed the proper irrigation decision for each period of the soil water content and amount of irrigation water at the start of the period were known. Finally, these results demonstrated that the irrigation amount could be substantially reduced without a large decrease in expected yield if the irrigation water was distributed optimally over the season. This study demonstrated the tremendous possibilities of applying the techniques of system simulation, dynamic programming and decision analysis to the irrigation problem.

74:03F-114
SIMULATION OF CROP RESPONSE TO ENERGY INPUTS,
Williams, D.W. and Chancellor, W.J.
VPI & SU, Blacksburg, Virginia, Agricultural Engineering Department.
Presented at 1974 Annual Meeting of the American Society of Agricultural Engineers, June 23-26, 1974. Stillwater, Oklahoma. 11 fig, 8 tab, 11 ref, 3 append.

Descriptors: *Mathematical models, Crop production, California, Simulation analysis.

Mathematical models of crop yields as a function of five energy-related inputs were developed for California agriculture. The models were used in a computer sumulation to determine the effects of shortages of the inputs upon total crop production.

74:03F-115
OPTIMIZING WATER UTILIZATION THROUGH MULTIPLE CROPS SCHEDULING,
Huang, W., Liang, T., and Wu, I.
Hawaii University, Honolulu, Agricultural Engineering Department.
Presented at 1974 Annual Meeting of the American Society of Agricultural Engineers, June 23-26, 1974. Stillwater, Oklahoma. 8 fig, 6 tab, 19 ref.

Descriptors: *Water utilization, Scheduling, Optimization, Linear programming, Model studies.

A deterministic linear programming model is developed for optimal use of water resources in a small Hawaiian reservoir system. Results from the application of the model show that through multiple cropping schemes, efficient use of water can be achieved and production acreage can be expahded.

74:03F-116
FIELD TEST OF SOIL WATER FLUX METERS,
Dirksen, C.
U.S. Salinity Laboratory, Riverside, California.
Presented at 1974 Annual Meeting of the American Society of Agricultural Engineers, June 23-26, 1974. Stillwater, Oklahoma. 4 fig, 1 tab, 5 ref.

Descriptors: *Soil water movement, Drainage, Soil investigations, Soil moisture, Soil properties.

Soil water flux in a draining soil profile was measured with flux meters featuring variable hydraulic resistances. As the hydraulic conductivity of the soil changes, the meter resistance is adjusted such that the overall hydraulic head loss across the meter matches that measured with tensiometers in undisturbed soil nearby. The soil water flux is then equal to that through the meter and is derived from the calibration of the resistance. If this match is not quite perfect, the remaining small amount of divergence or convergence of flow is calculated with an empirical relationship, independent of the magnitude of the flux and the hydraulic properties of the soil. The soil water fluxes were measured in essentially undisturbed soil, since the meters were installed from a horizontal direction. Such installation is possible by using a compression spring that pushes thin filter plates against the top and bottom of undisturbed soil surfaces excavated to a certain size with a specially designed apparatus. A slanted pin used to constrain the spring permits the meter to be installed and retrieved repeatedly. Two flux meters of different sizes and with different hydraulic resistances were tested side by side in a field plot and gave consistent, satisfactory results.

74:03F-117
"CHAMBER METHOD" FOR DRIP IRRIGATION SYSTEM DESIGN AND INSTALLATION PROCEDURES,
Pira, E.S.
Massachusetts University, Amherst, Food and Agricultural Engineering Department.
Presented at 1974 Annual Meeting of the American Society of Agricultural Engineers, June 23-26, 1974. Stillwater, Oklahoma. 6 fig, 2 tab, 6 ref.

Descriptors: *Irrigation design, *Head loss, *Design criteria, Irrigation methods, Flow rates, Irrigation, Agriculture.

High pressure water is supplied through a "quick-fill" and pressure reducing means to a low pressure distribution chamber. Relatively uniform pressure along the length of the chamber produces relatively uniform flow from the drippers. System designs, components, and installation procedures based on laboratory and field tests are discussed. Conclusions drawn from this work are: (1) Darcy's pressure loss equation and Bernoulli's flow equation provide a basis for designing chamber method irrigation systems; (2) Drippers with tubing segments attached as described will eliminate dripper failure problems; (3) The chambers must be charged rapidly for efficient system operation; (4) The diameter of the chamber is the determining factor which limits the number of drippers that can be used and the maximum chamber length; (5) Relatively uniform pressures can be maintained from the beginning to the end of the chamber, at low flow rates. Consequently, flow from the drippers is relatively uniform; and (6) Flow rates from the drippers can be adjusted by changing the pressure in the chamber.

74:03F-118
MOISTURE AVAILABILITY AND CROP PRODUCTION,
Hargreaves, G.H.
Utah State University, Logan.
Presented at 1974 Annual Meeting of the American Society of Agricultural Engineers, June 23-26, 1974. Stillwater, Oklahoma. 1 fig, 2 tab, 7 ref.

Descriptors: *Crop production, *Moisture availability, Moisture deficit, Evapotranspiration, Irrigation, Irrigation design.

Although yield data are available for agricultural crops at many locations, there is a scarcity of data relating yield to moisture availability. Improved evaluation of the effect of moisture could be accomplished through improved standardization and more uniformity in reporting procedures. Many interacting factors result in various levels of crop yields. However, there is a surprising degree of uniformity in response to level of moisture availability when data from various experiments are analyzed in a standardized manner. General acceptance of more complete and thorough methods for the quantitative evaluation of moisture deficiencies will improve the valuation of climate as a resource to be considered in development. The metholology given also provides a useful tool for irrigation development planning, irrigation design and the scheduling of irrigation applications.

74:03F-119
GRAIN SORGHUM EVAPOTRANSPIRATION AND WATER USE EFFICEINCY UNDER TRICKLE IRRIGATION,
Howell, T.A. and Hiler, E.A.
Texas A&M University, College Station, Department of Agricultural Engineering.
Presented at 1974 Annual Meeting of the American Society of Agricultural Engineers, June 23-26, 1974. Stillwater, Oklahoma. 5 fig, 3 tab, 38 ref.

Descriptors: *Grain sorghum, *Evapotranspiration, *Irrigation practices, Irrigation systems, Irrigation.

This research demonstrates a potential for increasing WUE of grain sorghum by utilizing trickle irrigation to apply frequent, but small irrigation quantities and limiting these applications according to the stage of plant development. The findings of this research indicate that water deficits which occur before the milk to soft dough stage of grain sorghum development can reduce yield and water use efficiency. However, careful regulation of the irrigation quantity to minumize water deficits during those periods can increase water use efficiency. Stage II (boot to bloom) is the most critical period. Utilizing an existing soil water balance model to determine plant transpiration further reinforced this conclusion when the yield per unit of transpired water was computed.

74:03F-120
COMPARING TRICKLE, SUBSURFACE AND SPRINKLER IRRIGATION SYSTEMS,
Brosz, D.D. and Wiersma, J.L.
South Dakota State University, Brookings, Water Resources Institute.
Presentes at 1974 Annual Meeting of the American Society of Agricultural Engineers, June 23-26, 1974. Stillwater, Oklahoma. 5 fig, 7 tab, r ref.

Descriptors: *Subsurface irrigation, *Sprinkler irrigation, Irrigation systems, Crop response, Corn, Potatoes, Irrigation efficiency.

Three years of data was collected on yield responses of potato and hybrid corn crops irrigated by trickle, subsurface, and sprinkler irrigation systems. The study was conducted on field plots which included six irrigation system design treatments that were replicated three times. The design treatments included every row and every other row trickle and subsurface irrigation, small frequent sprinkler application, and larger, less frequent sprinkler applications. Indications are that potato and corn production could be increased by 5 to 15 percent with 20 percent less water applied through the use of trickle and subsurface irrigation. A water savings in the neighborhood of 30 to 40 percent could possibly be achieved with trickle and subsurface irrigation for yields that are essentially the same as those obtained with sprinkler irrigation. Tricke and subsurface irrigation systems do allow for a more efficient water management operation. Tensiometers installed in the research plots did show that the soil water tension was higher for the trickle and subsurface plots. The irrigation system design treatments had no effect on potato crop maturity or quality. The sprinkler irrigation system design that applied small, frequent water depths did have an effect on the grain quality of a corn crop in the black masses of spores that appeared on the ears of the corn plant.

74:03F-121
A COMPARISON OF N-DEPLETED AND N-ENRICHED FERTILIZERS AS TRACERS,
Starr, J.L., Broadbent, F.E., and Stout, P.R.
California University, Davis, Department of Soils and Plant Nutrition.
Soil Science Society of America Proceedings, Vol. 38, No. 2, p 266-267, March-April, 1974. 1 fig, 1 tab, 3 ref.

Descriptors: Fertilization, Nitrogen, Isotope studies, Crop response.

((14)NH4)2SO4 from which virtually all (15)N had been removed was compared as a tracer with (NH4)2SO4 containing 8.95% (15)N excess in a plant uptake experiment using soil columns maintained at 1/3 bar tension and conventional greenhouse pots. Uptake of fertilizer nitrogen in three cuttings of ryegrass was identical with the two fertilizers. Estimates of residual fertilizer N in the pots agreed less closely, owing to the high dilution factor.

74:03F- 122
INFLUENCE OF ORGANIC NITROGEN ON SOIL NITROGEN, NODULATION, NITROGEN FIXATION, AND YIELD OF SOYBEANS,
Bezdicek, D.F., Mulford, R.F., and Magee, B.H.
Maryland University, Department of Agronomy.
Soil Science Society of America Proceedings, Vol. 38, No. 2, p 268-273, March-April, 1974. 2 fig, 5 tab, 17 ref.

Descriptors: *Fertilization, Nitrogen, Nitrogen fixation, Soybeans, Crop response.

Nitrogen was applied on a previous rye cover crop for later determination of the effect of organic N on soybean, N2-fixation rate, plant dry matter, N uptake, and yield. Nitrogen was applied at, 0, 56, 112, and 224 kg N/ha as NH4NO3 or urea either on rye in mid-March or at soybean planting time in a 4 x 2 x 2 factorial design. In both years of study, N2-fixation rate as estimated from acetylene reduction was reduced throughout the season by increased fertilization rate. For 1 year, interactions showed that N2-fixation rate and nodule mass were stimulated late in the season from increased N fertilizer applied to the rye but not at soybean planting. Interactions between NH4NO3 as compared with urea and time of application showed that NH4NO3 as compared with urea applied on rye significantly increased soybean dry matter, N uptake, and yield. Urea applied at planting increased these parameters in comparison with NH4NO3. The observed increases in dry matter, N uptake, and yield from rye-applied NH4NO3 were not accompanied by a corresponding increase in N2-fixation rate or nodule mass. This would suggest that the N2 fixing system was not responsible for the increase of dry matter, N-uptake, and yield. Soil organic N was not measureably influenced by the treatments imposed.

74:03F-123
SOIL PHOSPHORUS AVAILABILITY AS MEASURED BY DISPLACED SOIL SOLUTIONS, CALCIUM-CHLORIDE EXTRACTS, DILUTE-ACID EXTRACTS, AND LABILE PHOSPHORUS,
Soltanpour, P.N., Adams, F., and Bennett, A.C.
Colorado State University, Ft. Collins, Dept. of Agronomy.
Soil Science Society of America Proceedings, Vol. 38, No. 2, p 225-228, March-April, 1974. 4 fig, 17 ref.

Descriptors: Fertilizers, Fertility, Soil tests, Sorghum, Crop response, Phosphorus.

Five rates of Ca(OH)2 and four rates of Ca(H2PO4)2-H20 were added in all combinations to samples of a P-deficient, low pH, sandy loam soil. The treated soil was subjected to several wetting-drying-pulverizing cycles to facilitate equilibrium. Soil solutions were subsequently displaced from subsamples and analyzed; other subsamples were extracted for P with CaCl2 and silute acid; "labile P" was determined on subsamples from each treatment; a sorghum-sudangrass hybrid was grown in the greenhouse to measure P availability.
Maximum yield of test plants was obtained at about 22 micro-m of P in the displaced soil solution, 12 micro-m of P in the CaCl2 extract, 80 ppm P on soil-weight basis in dilute-acid extract, and 50 ppm of "labile P" on soil-weight basis. The P uptake was highly correlated with the logarithm of P concentration in soil solution and CaCl2 extract, logarithm of "labile P" and concentration of P in dilute acid extract. All index were nearly equal as indicators of P availability.

74:03F-124
RATE OF PHOSPHORUS SORPTION BY FIVE OKLAHOMA SOILS,
Enfield, C.G.
National Water Quality Control Research Program.
Soil Science Society of America Proceedings, Vol. 38, No. 3, p 404-407, May-June, 1974. 7 fig, 1 tab, 14 ref.

Descriptors: Fertilizers, Fertilization, Phosphorus, Equations, Sorption, Oklahoma.

Two equations are evaluated in relation to their suitability as rate equations for phosphorus sorption by selected Oklahoma soils. The rate equation which best fits experimental data was ds/dt = a(C to the b power)(S to the c power) where S is the sorbed concentration (mass per unit weight of the soils), C is solution concentration (mass per unit weight of the solution), t is time and a, b. and c are constants.

74:03F-125
ACCRETION AND DILUTION OF NUTRIENTS IN YOUNG CORN, AS AFFECTED BY YIELD RESPONSE TO NITROGEN, PHOSPHORUS, AND POTASSIUM,
Terman, G.L. and Allen, S.E.
Tennessee Valley Authority, Muscle Shoals, Alabama, National Fertilizer Develop-

ment Center, Soils and fertilizer Research Branch.
Soil Science Society of America Proceedings, Vol. 38, No. 3, p 455-460, May-June, 1974. 5 fig, 1 tab, 13 ref.

Descriptors: Fertilizers, Nutrient removal, Nutrients, Nitrogen, Phosphorus, Potassium, Corn, Crop response.

Hybrid corn was grown in infertile soil fertilized with none and three nonzero rates of N, P, or K, in separate treatment series; other nutrients were applied in each series at uniform levels. Near-linear increases in uptake of N, P, or K with amount applied occurred during 25, 41, and 53 days' growth. Concentrations of N,P, or K increased with amount applied and decreased with continued growth in each series; uniformly applied P and K, N and K, or N and P were diluted with increase in dry matter resulting from continued growth and yield response to increasing amounts of the third nutrient. Yield-concentration relationships in the N response series were similar for N, Ca, Mg, Mn, and Zn. Response to P or K resulted in dilution of all other nutrients. Concentrations of total cations increased with concentrations of N in each response series; the reverse was true with P and K. Thus, the results suggest that a positive relationship between dry matter yields and total cations (C), total inorganic anions (A), and C-A depends on whether yield response is due to N or to other growth-limiting factors.

74:03F-126
A TWO-PHASE MODEL FOR THE MISCIBLE DISPLACEMENT OF REACTIVE SOLUTES IN SOILS,
Skopp, J. and Warrick, A.W.
Arizona University, Tucson, Department of Soils, Water and Engineering.
Soil Science Society of America Proceedings, Vol. 38, No. 4, p 545-550, July-August, 1974. 5 fig, 1 tab, 32 ref.

Descriptors: *Modes studies, Solutes, Adsorption, Deffusion, Connection.

Miscible displacement is studied by considering the flow regime to be composed of separate mobile and stationary phases. Solute transfer through the mobile phase occurs only by convection, whereas adsorption or reaction by the soil matrix is diffusion limited and occurs normal to the mobile-stationary interface. The model is unique in that a specific rate law is not assumed, but the solution is exact. Results are presented graphically as a function of two parameters which are compared with experimental results of other workers. The displacement of calcium by magnesium was more closely in agreement with theoretical predictions than was adsorption of picloram.

74:03F-127
TIME-DEPENDENT LINEARIZED INFILTRATION: II. LINE SOURCES,
Lomen, D.C. and Warrick, A.W.
Arizona University, Tucson, Dept. of Mathematics.
Soil Science Society of America Proceedings, Vol. 38, No. 4, p 568-572, July-August, 1974. 6 fig, 12 ref.

Descriptors: *Infiltration, *Soil water movement, *Mathematical studies, *Unsaturated flow, *Soil water, Irrigation practices, Irrigation effects, Irrigation systems, Irrigation, Agriculture, Irrigation water.

Water flow from line sources is analyzed using a linearized form of the moisture flow equation. Both single and parallel line sources are considered. Results are particularly relevant for high-frequency irrigation such as by trickle sources, for which the soil moisture at any particular point varies over a relatively small range. Numerical calculations include lines of constant matric flux potential (or equal moisture content) as a fucntion of time and the time-dependent response to a cyclic input. Although the results are developed for surface sources, the analysis may easily be extended to buried sources.

74:03F-128
SOLUTION TO THE ONE-DIMENSIONAL LINEAR MOISTURE FLOW EQUATION WITH WATER EXTRACTION,
Warrick, A.W.

Arizona University, Tucson, Dept. of Soils, Water and Engineering.
Soil Science Society of America Proceedings, Vol. 38, No. 4, p 573-576, July-August, 1974. 3 fig, 2 tab, 8 ref.

Descriptors: *Soil water movement, *Infiltration, *Mathematical studies, *Unsaturated flow, *Soil water, Irrigation practices, Irrigation effects, Irrigation systems, Irrigation, Agriculture, Irrigation water.

The one-dimensional, steady-state moisture flow equation is solved for arbitrary plant water withdrawal functions using the matric flux potential of earlier investigators to obtain a linearized form. A semi-infinite flow medium and a finite-depth medium overlying a shallow water table are considered with the surface boundary condition taken as a flux. Tables are presented giving the matric flux potential (from which the pressure head is easily determined) for several withdrawal functions. Numerical examples show the effects of different surface fluxes and rooting depths on the matric flux potential and pressure-head profiles. The results are particularly relevant for high-frequency irrigation.

74:03F-129
EFFECT OF SALTS AND SALTS PLUS NITROGEN-15-LABELED AMMONIUM CHLORIDE ON MINERALIZATION OF SOIL NITROGEN, NITRIFICATION, AND IMMOBILIZATION,
Westerman, R.L. and Tucker, T.C.
Arizona University, Tucson, Department of Soils, Water and Engineering.
Soil Science Society of America Proceedings, Vol. 38, No. 4, p 602-605, July-August, 1974. 1 fig, 5 tab, 11 ref.

Descriptors: *Nitrogen, *Nitrification, Salinity, Salts, Ammonium compound.

The effects of 0.0, 0.01, and 1.0 N concentrations of sodium, copper and calcium chloride salts added to a Pima clay loam with and without (15)NH4Cl on mineralization of soil nitrogen, nitrification, and immobilization were measured over a 49-day period. Dilute concentrations of salt, (15)NH4Cl, and dilute salts plus (15)NH4Cl stimulated mineralization of soil N. The "priming effect" was shown to be real and not just a simple exchange. Nitrification of native ammonium nitrogen and (15)N-labeled ammonium decreased with increasing concentrations of salt. High concentrations of copper and calcium chloride salts inhibited nitrification of (15)N-labeled ammonium more than sodium salts. Immobilization of (15)NH4(+)-N was decreased significantly by high concentrations of salt. Gaseous loss processes were decreased with increased salts.

74:03F-130
WATER REPELLENT SOIL MULCH FOR REDUCING FERTILIZER NUTRIENT LEACHING: II. VARIABLES GOVERNING THE EFFECTIVENESS OF A SILICONE SPRAY,
Snyder, G.H., Ozaki, H.Y., and Hayslip, N.C.
Dow Corning Corporation, Midland, Michigan.
Soil Science Society of America Proceedings, Vol. 38, No. 4, p 678-681, July-August, 1974. 4 tab, 7 ref.

Descriptors: *Mulching, *Nitrogen, Potassium, *Leaching, *Nutrients, Sweet Corn.

Nitrogen and potassium from a fertilizer band in sand soils was reduced by creating a mulch of water repellent soil over the band using a siliconate spray. Best results were obtained using a 1% siliconate spray in quantities sufficient to penetrate about 4 cm over a region 20 cm wide, on the flat surface of raised vegetable beds. Mulches created on peaked beds were ineffective in reducing leaching, probably due to erosion of the mulch. Sweet corn yields are comparable to those obtained by protecting N and K with plastic mulch or by applying N and K in split applications.

74:03F-131
PREDICTING EXCHANGEABLE SODIUM RATION IN IRRIGATED TROPICAL VERTISOLS,
Sinanuwong, S. and El-Swaify, S.A.
Hawaii Institute of Geophysics.

Soil Science Society of America Proceedings, Vol. 38, No. 5, p 732-737, September-October, 1974. 7 fig, 7 tab, 12 ref.

Descriptors: *Sodium, Hawaii, Soil properties, Soil chemical properties, Soil chemistry, Soil tests.

Batch equilibrium studies were used to investigate Nadivalent exchange and to derive Capon constants for three Hawaii Vertisols. Obtained regression coefficient values indicated that a linear relationship exists between exchangeable sodium ration (ESR) and sodium adsorption ratios (SAR) for tropical Vertisols. ESR values obtained for two of the soils were slightly lower than the values predicted by Bower's equation and higher than those predicted by the U.S. Salinity Laboratory's equation. ESR values obtained for the third soil were lower than those predicted by either equation. Generally, the higher preferences fo surface than of subsurface horizons for Na was confirmed. Prevailing electrolyte concentration levels were found more important than any other experimental variable on affecting the precision fo ESR estimates for a given SAR. Although ESR values were generally higher at 0.1N, the valence-dilution effect was reversed for the surface horizon of one Vertisol during Mg-Na exchange. While little difference was noted between Ca-Na and Mg-Na exchange in one of the soils, in the other two significantly smaller ESR values were obtained for the first than for the second reaction. An unexpected type of hysteresis effect was noted, whereby divalent-soils exhibited greater preference for Na than did Na-soils. Possible reasons for this effect are discussed.

74:03F-132

NITRIFICATION AND DENITRIFICATION DURING MISCIBLE DISPLACEMENT IN UNSATURATED SOIL,

Kirda, C., Starr, J.L., Misra, C., Biggar, J.W., and Nielsen, D.R.
California University, Davis, California.
Soil Science Society of America Proceedings, Vol. 38, No. 5, p 772-776, September-October, 1974. 5 fig, 1 tab, 15 ref.

Descriptors: *Nitrification, *Denitrification, Leaching, Diffusion, Soil water, Soil properties, Soil chemistry, Unsaturated flow.

Nitrification and denitrification during the leaching of a pulse of NH4NO3 applied to the surface of soil columns are analyzed experimentally and theoretically. Experimentally, unsaturated soil columns of two lengths were leached steadily with a tracee solution containing NH4NO3 while the air-filled portions of the columns were being flushed simultaneously with air. During these steady state conditions, a pulse of tracer solution containing either 15NH4(+) or 15NO3(-) was leached through the columns. The words tracee and tracer signify that both solutions were chemically identical with the latter containing a greater proportion of 15N. Steady-state tracee concentration distributions within the columns as well as the transient tracer concentration distributions in the effluent were analyzed assuming first-order kinetics. Values of both the rate coefficients and the concentration distributions stemming from the tracee and tracer measurements were in general agreement. The agreement between the measured and theoretical results are discussed in terms of soil water properties and the kinetics of microbial populations.

74:03F-133

SALT TOLERANCE OF MEXICAN WHEAT: II. RELATION TO VARIABLE SODIUM CHLORIDE AND LENGTH OF GROWING SEASON,

Bernal, C.T., Bingham, F.T., and Oertli, J.
California University, Riverside, Department of Soil Science and Agricultural Engineering.
Soil Science Society of America Proceedings, Vol. 38, No. 5, p 777-779, September-October, 1974. 7 fig, 2 tab, 15 ref.

Descriptors: *Wheat, Crop response, Crop production, Germination, Salinity, Salt tolerance.

Germination, seedling growth, and grain production of four short-season, one intermediate-season, and three long-season varieties of Mexican wheat were studied in relation to variable NaCl salinity. Germination counts after 7 days exposure to NaCl solutions in petri dishes revealed that the wheats as a group are relatively tolerant, germinating freely in the presence of -16 to 20-atm osmotic potential. Tolerance at germination was not associated with any obvious properties such as length of growing season or seed hardness. The eight wheat varieteis were grown from seedling stage to maturity on sand cultures with a complete nutrient solution containing sufficient NaCl to produce total osmotic potentials of 0.5, 2.5, and 4.5 atm. Plots of relative grain yield in relation to osmotic potential of substrate revealed two general relationships, one for the short-season varieties and one for the long-season varieties.

74:03F-134
RICE RESPONSE TO NITROGEN AND PHOSPHORUS IN FLOODED AND NONFLOODED SOILS,
Terman, G.L. and Allen, S.E.
Tennessee Valley Authortiy, Muscle Shoals, Alabama, National Fertilizer Development Center, Soils and Fertilizer Research Branch.
Soil Science Society of America Proceedings, Vol. 38, No. 5, p 780-784, September-October, 1974. 3 fig, 5 tab, 12 ref.

Descriptors: *Rice, Nitrogen, Nitrification, Phosphorus, Crop response, Greenhouse, Flood irrigation, Flooding.

Pot experiments were conducted in a greenhouse to study nutrition of rice under flooding and upland conditions. Yields of rice grown in one experiment on Mountview silt loam increased rectilinearly with 0-, 400-, and 800-mg rates of N/pot (5 kg of soil). Concentrations of N in grain + straw at maturity were uniformly low. Multiple rates of N from 250 to 2,000 mg/pot and P from 0 to 1,000 mg/pot (6.25 kg of soil) were applied for Nato rice grown on Mountview silt loam and Sango silty clay loam in a second experiment. Marked yield responses to N and P were obtained. Yields of straw and of grain + straw, N uptake, and N recovery were higher on nonflooded than on flooded soils. Grain yields, however, were slightly higher with flooding. Uptake of N, P, Ca, Mg, Mn, and Zn increased with yield response to N and P, while K uptake decreased on the Mountview soil. Concentrations of N and P increased with applied N and P, respectively, while concentrations of other nutrients were diluted in most situations with yield response to N or P on both flooded and nonflooded soils. These results indicate that with adequate applied nitrients, especially N, yields of rice with adequate water but without flooding can equal or even exceed those under flooding.

74:03F-135
MODIFIED PENMAN EQUATION TO PROVIDE THE UPPER BOUNDARY CONDITION ON COMPUTING EVAPORATION FROM SOIL,
Staple, W.J.
Soil Research Institute, Agriculture Canada, Ottowa, Ontario.
Soil Science Society of America Proceedings, Vol. 38, No. 5, p 837-839, September-October, 1974. 2 fig, 16 ref.

Descriptors: *Evaporation, Vapor pressure, Soil, Soil water movement, Drying.

Penman's equation for potential evaporation was modified by including in it the relative vapor pressure h of partially dried surface soil. The modified equation was used to predict evaporative flux from drying soil as a boundary condition in the finite difference solution of the flow equation. The method gave satisfactory agreement in a 20-day test in which evaporation was measured from short columns of soil in a fallowed plot.

74:03F-136
DIURNAL SOIL-WATER EVAPORATION: COMPARISON OF MEASURED AND CALCULATED SOIL-WATER FLUXES,
Jackson, R.D., Reginato, R.J., Kimball, B.A., and Nakayama, F.S.
U.S. Water Conservation Laboratory, Phoenix, Arizona.
Soil Science Society of America Proceedings, Vol. 38, No. 6, p 861-866, November-December, 1974. 8 fig, 2 tab, 20 ref.

Descriptors: Soil water movement, Soil water, Diffusivity, Evaporation, Theoretical analysis.

The Philip and DeVries theory and the "isothermal" theory were used to predict diurnal soil water fluxes near the soil surface. The predicted values were compared with those obtained by measurements of soil-water content, soil temperature, and evaporation. Previously measured soil-water diffusivities were used in the theoretical calculations. The thermal vapor diffusivities were calculated using both the "simple" and the "complete" theory of Philip and DeVries. Comparison of measured and calculated fluxes indicated that the theory of Philip and DeVries predicts the measured values better at intermediate water contents, but the "isothermal" theory predicts values better at high and very low water contents.

74:03F-137
TWO-DIMENSIONAL WATER INFILTRATION FROM A TRENCH IN UNSATURATED SOILS,
Sawhney, B.L. and Parlange, J.-Y.
Connecticut Agricultural Experiment Station, New Haven.
Soil Science Society of America Proceedings, Vol. 38, No. 6, p 867-871,
November-December, 1974. 8 fig, 2 tab, 10 ref.

Descriptors: *Infiltration, Trenches, Unsaturated flow, Soil water movement Moisture tension, Seepage.

Two-dimensional infiltration of water from finite trenches was observed in three soil samples with different textures. The vertical infiltration is slowed by the lateral infiltration and the slowing is inversly proportional to the width of the trench. Furthermore, the vertical infiltration is about twice as fast as the lateral infiltration for all soils tested. At the same relative distance from the trench, the soil was drier beside than below the trench. Our observation and interpretations agree with numerical simulations of Selim and Kirkham.

74:03F-138
NOMOGRAPHIC INTERPRETATION OF WATER ABSORPTION DATA IN TERMS OF A TWO-PARAMETRIC DIFFUSIVITY-WATER CONTENT FUNCTION,
Stroosnijder, L. and Nolt, G.H.
State Agricultural University, Wageningen, The Netherlands, Dept. of Soils and Fertilizers,
Soil Science Society of America Proceedings, Vol. 38, No. 6, p 876-880,
November-December, 1974. 5 fig, 2 tab, 13 ref.
(See 74:02G-030)

74:03F-139
UNSTEADY, UNSATURATED, N-DIMENSIONAL MOISTURE FLOW IN SOIL: A COMPUTER SIMULATION PROGRAM,
Van der Ploeg, R.R. and Benecke, P.
Georg-August University, Goettingen, West Germany.
Soil Science Society of America Proceedings, Vol. 38, No. 6, p 881-884,
November-December, 1974. 7 fig, 1 tab, 15 ref.

Descriptors: *Computer models, *Computer programs, *Simulation analysis, Mathematical models, Unsaturated flow, Soil water movement, Unsteady flow, Soil water, Absorption.

A computer simulation program for prediction n-dimensional moisture flow in soils is simple to program and does not require extensive mathematical background. The programming was done with the computer program System/360 Continuous System Modeling Program (CSMP). For a number of selected problems the simulation results were compared with existing analytical and numerical solutions, and good agreement was found. Comparisons are made for 1-dimensional adsorption, 3-dimensional (spherical) absorption, 2-dimensional filtration from a line-source and a 3-dimensional infiltration from a point source.

74:03F-140
COMPARATIVE EFFICIENCY OF SOLUBLE AND CONTROLLED-RELEASE SULFUR-COATED UREA NITROGEN FOR CORN IN TROPICS,
Dalal, R.C.
West Indies University, St. Augustine, Trinidad.
Soil Science Society of America Proceedings, Vol. 38, No. 6, p 790-794, November-December, 1974. 3 fig, 5 tab, 11 ref.

Descriptors: *Nitrogen, *Urea, *Nitrification, Corn, Crop response, Nutrients.

The efficiency of the soluble-N sources, ammonium sulfate (AS), urea-ammonium phosphate (UAP) and urea and controlled-release-N source, sulfur-coated urea (SCU-8.9, SCU-1.1, and SCU-0.9) of differing N-release rates applied at 50, 100, and 200 kg/ha of N to an acidic soil, were compared in terms of N uptake and grain yield of corn. The apparent N recovery of added N, calculated by uptake differences from the control plots, was evaluated from N uptake by the two successive crops, one in the wet season and the other in the following dry season. In general, N uptake, grain yield, and apparent N recovery were increased by added N; which was opposite to the nitrification of these N sources except that the performance of urea was better than the other soluble-N sources, primarily because it had a smaller effect on soil pH and exchangeable Al. The inclusion of microbicide in the S-coatings of SCU had no influence on N efficiency or grain yield. More N was recovered from SCU with slower N-release characteristics irrespective of coating weight. Apparent recovery of added N was almost complete from urea, SCU-8.9, SCU1.1 and SCU-0.9 when applied at the rate of 50 kg/ha of N, although the recovery at 200 kg/ha of N was about 50%.

74:03F-141
A METHOD FOR MEASURING FIRST-STAGE SOIL WATER EVAPORATION IN THE FIELD,
Arkin, G.F., Rithcie, J.T., and Adams, J.E.
Texas Agricultural Experiment Station.
Soil Science Society of America Proceedings, Vol. 38, No. 6, p 951-954, November-December, 1974. 5 fig, 8 ref.
(See 74:07B-006)

74:03F-142
RELATION BETWEEN NITRATE ABSORPTION AND WATER TRANSPIRATION BY CORN,
Liao, C.F.-H. and Bartholomew, W.V.
North Carolina State University, Raleigh, Department of Soil Science.
Soil Science Society of America Proceedings, Vol. 38, No. 3, p 472-477, May-June, 1974. 5 tab, 17 ref.

Descriptors: Nitrates, Absorption, Transpiration, Leaching, Corn, Crop response, Evapotranspiration, Diffusion.

The relationship between the absorption of NO3-N by young corn plants and the quantity of water transpired was studied in solution and soil culture. Tracer N was employed to measure NO3 absorption. Gravimetric methods were used to monitor evapotranspiration. From solution culture, NO3 was absorbed at rates relatively greater than water. From soil culture, NO3 was absorbed at a relative rate close to that of water when the soil was not pretreated. However, when the soil material was wetted and leached of soluble N before planting corn, NO3 was absorbed at a relative rate 1.5 to 2.0 times that of water. In soil situations where water was not being absorbed by plants, NO3-N likewise was not absorbed. Mass flow and diffusion both were involved in NO3 transport to roots. Prior cultural conditions had a marked influence on active uptake of NO3 presumably through an influence on speicfic rates of N absorption.

74:03F-143
EFFECT OF TRANSPIRATION RATE ON SALT ACCUMULATION AROUND CORN ROOTS IN A SALINE SOIL,
Sinha, B.K. and Singh, N.T.
Punjab Agricultural University, Ludhiana, India, Department of Agricultural Engineering.
Agronomy Journal, Vol. 66, No. 4, p 557-560, July-August, 1974. 1 fig, 3 tab, 11 ref.

Descriptors: *Saline soil, Salinity, Ions, Transpiration, Salts, Corn root zone.

Laboratory studies were conducted to determine the extent of ion accumulation around corn roots of plants exposed to different transpiration conditions. Ion accumulation in the apparent free space of roots, the soil adhering to the roots, and the bulk soil was studied using a soil mixed with sodium chloride so that the electrical conductivity of saturation extract was 3.96 mmho/cm. Maximum ion accumulation occurred in the apparent free space of the roots, followed by the closely adhering soil. Under high transpiration, sodium concentration increased from 37.6 mg/100 g in the bulk soil to 90.3 mg/100 g in the soil close to the roots. After the same treatment, a threefold increase in the chloride content of the closely adhering soil was observed. A significant correlation existed between the rate of water loss per unit root length and the Na and Cl concentration of the closely adhering soil. Results indicate that under high transpiration, the salt concentration close to the roots may be much higher than that obtained from an analysis of the bulk soil.

74:03F-144
MODEL FOR PREDICTING PLANT YIELD AS INFLUENCED BY WATER USE,
Hanks, R.J.
Utah State University, Logan, Department of Soil Science and Biometerorology.
Agronomy Journal, Vol. 66, No. 5, p 660-665, September-October, 1974.
6 fig, 4 tab, 22 ref.

Descriptors: *Consumptive use, *Growth rates, *Model studies, Irrigation practices, Irrigation methods, Computer models, Evaporation, Transpiration, Moisture availability.

A model has been devised to predict plant yield, both total dry matter and grain, as a function of water use. The model is simple and inexpensive to run on a computer to determine seasonal yields as influenced by irrigation frequency and amount, rainfall, matter yield of sorghum in Colorado, corn dry matter and grain yields in Israel, and corn grain yields in Nebraska, with various water application treatments, was found. A basic assumption is that the ratio of actual to potential transpiration. Evaporation from the soil is assumed to decrease with the square root of time after wetting as well as with the stage of growth. The shape of the relative yield-water use curve was found to be sensitive to the evaporation and transpiration assumptions made, but insensitive to the relation used to describe the influence of soil water status on transpiration.

74:03F-145
IRRIGATION, ROW WIDTH, AND PLANT POPULATION IN RELATION TO GROWTH CHARACTERISTICS OF TWO SOYBEAN VARIETIES,
Doss, B.D. and Thurlow, D.L.
United States Department of Agriculture, Agricultural Research Service, Auburn, Alabama.
Agronom- Journal, Vol. 66, No. 5, p 620-623, September-October, 1974. 2 fig, 5 tab, 8 ref.

Descriptors: *Soybeans, *Crop response, *Plant population, Irrigation, Moisture stress, Irrigation practices, Soil water, Plant growth, Planting management.

Soybean yields in the past have varied considerably from year to year in the southeastern United States. Many factors are important in soybean production, but water stress at critical growth periods appears to be one of the most frequently limiting factors. Soybeans were grown on a Lucedale fine sandy loam soil to determine the effects of three soil water regimes at two row widths and three plant population levels on water use, rate of plant growth, and bean yield of two varieties. Water use rates by soybeans were influenced more by soil water regime than by row width or variety. Average rates during the season ranged from 0.05 to 0.84 cm/day, depending on the amount of available water in the soil.

74:03F-146
EFFECT OF SOIL WATER STRESS AT VARIOUS GROWTH STAGES ON SOYBEAN YIELD,
Doss, B.D., Pearson, R.W. and Rogers, H.T.
United States Department of Agriculture, Agricultural Research Service, Auburn, Alabama.
Agronomy Journal, Vol. 66, No. 2, p 297-299, March-April, 1974. 1 fig, 2 tab, 11 ref.

Descriptors: *Moisture stress, *Soybeans, *Crop response, *Growth stages, Irrigation practices, Irrigation effects, Irrigation.

Conventional irrigation experiments and rainfall distribution-yield studies have indicated that insufficient water during flowering and pod-fill stages frequently limits yields of soybeans. In this 3-year experiment, field plot covers were used to control rainfall and water stress was imposed on plants at various stages of growth to determine more specifically the critical periods for irrigating soybeans for maximum yields. Soil water regimes ranged from a limited supply (10% available soil water) to adequate water (50% available) during the entire growing season. More bean production was obtained from water applied after full bloom than earlier. The pod-fill stage, from August 15 to September 20 for 'Bragg' soybeans at Thorsby, Alabama, was the critical time for adequate water for maximum yields. Yields from adequately watered soybeans were 540 to 1,040 kg/ha, or 24 to 55%, greater than where water was limited throughout the growing season. Highest yield obtained under the best water regime was 3,320 kg/ha. Conditions limiting yields were not obvious.

74:03F-147
DESIGNING TRICKLE IRRIGATION LATERALS FOR UNIFORMITY,
Howell, e.A. and Hiler, E.A.
Texas A&M University, College Station, Department of Agricultural Engineering.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 100, No. IR4, p 443-454, December, 1974. 9 fig, 11 ref, 2 append.
(See 74:08A-002

74:03F-148
ECONOMIC PIPE SIZING IN PUMPED IRRIGATION SYSTEMS,
Perold, R.P.
Stellenbosch University, Republic of South Africa, Department of Agricultural Engineering.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 100, No. IR4, p 425-551, December, 1974. 7 fig, 1 tab, 11 ref, 2 append.
(See 74:08A-003

74:03F-149
SURFACE PLUGGING DURING BASIN RECHARGE OF TURBID WATER,
Jones, O.R., Goss, D.W., and Schneider, A.D.
United States Department of Agriculture, Southwestern Great Plains Research Center, Bushland, Texas.
Transactions of the ASAE, Vol. 17, No. 6, p 1011-1014 & 1019, November-December 1974. 7 fig, 2 tab, 9 ref.

Descriptors: *Recharge, *Recharge ponds, Groundwater, Groundwater basins, Groundwater recharge, Turbidity.

The following conclusions were made as a result of investigations on the Southern High Plains to artificially recharge the Ogallala aquifer with turbid storm runoff through excavated basins: 1) Most suspended solids in playa water were deposited on or near the surface during basin recharge, except during test where cracking of the basin surface while flooded allowed sediment deposition at undetermined depths below the basin surface; 2) Although plugging was related to the amount of suspended solids introduced into the basin with the recharge water, the total amount of suspended solids required to cause plugging varied by an order of magnitude between tests; 3) The major factor limiting recharge of tubid water through excavated basins was plugging on or near the surface.

74:03F-150
MIXING IN SPRINKLER IRRIGATION SYSTEMS,
Hermann, G.J., McMaster, G.M. and Fitzsimmons, D.W.
CH2M/Hill, Redding, California, Agricultural Engineering.
Transactions of the ASAE, Vol. 17, No. 6, p 1020-1024 & 1028, November-December 1974. 6 fig, 9 ref.
(See 74:08A-004)

74:03F-151
ANALYSIS OF CANAL SEEPAGE TO INTERCEPTOR DRAIN,
Sharma, H.D. and Chawla, A.S.
U.P. Irrigation Research Institute, Roorkee, India.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 100, No. IR3, p 351-369, September, 1974. 11 fig, 5 ref, 2 append.
(See 74:08A-006)

74:03F-152
IRRIGATION MANAGEMENT FOR SALT CONTROL,
van Schilfgaarde, J., Bernstein, L., Rhoades, J.D. and Rawlins, S.L.
United States Department of Agriculture, Riverside, California, Agricultural Research Service, U.S. Salinity Laboratory.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 100, No. IR3, p 321-338, September, 1974. 8 fig, 5 tab, 27 ref, 2 append.

Descriptors: Salinity, Saline soil, Saline water, Irrigation effects, Irrigation practices, Irrigation operation and maintenance, Irrigation water.

Combination of a reevaluation of established crop salt tolerance data, recent advances in understanding of soil chemistry and application of soil physics principles leads to a proposed management system for irrigation that can result in significant reductions in the amount of salt discharged for irrigation projects. These concepts can play a major part in advancing irrigation agriculture, while meeting the challenge of minimizing water quality degradation. Adoption will require changes in irrigation management that call for far closer control of amount and uniformity of water applied than is customary.

74:03F-153
BASIC PRINCIPLES OF PULSE IRRIGATION,
Karmeli, D. and Peri, G.
Technion, Haifa, Israel, Faculty of Agricultural Engineering.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 100, No. IR3, p 309-319, September, 1974. 2 fig, 3 tab, append.

Descriptors: Irrigation systems, Irrigation practices, Irrigation effects, Irrigation design, Sprinkler irrigation, Application methods, Water conservation.

The term pulse irrigation was defined qualitatively and quantitatively. This irrigation technique was described in terms of its main purpose which is the achievement of low application rate with the use of an irrigation device having a higher application rate. The present analysis based on mathematical and engineering considerations enables the determination of the characteristics of pulse irrigation (e.g., length of operating and resting time in a single pulse and the number of pulses).

74:03F-154
QUANTITY AND FREQUENCY OF TRICKLE AND FURROW IRRIGATION FOR EFFICIENT CABBAGE PRODUCTION,
Bucks, D.A., Erie, L.J. and French, O.F.
U.S. Water Conservation Laboratory, Phoenix, Arizona.
Agronomy Journal, Vol. 66, No. 1, p 53-57, January-February, 1974. 4 fig, 3 tab, 9 ref.

Descriptors: *Crop production, *Crop response, *Consumptive use, *Evapotranspiration, Irrigation practices, Irrigation systems, Irrigation efficiency, Irrigation, Agriculture.

Trickle irrigation, with its capability of small, frequent irrigation applications, has aroused considerable interest because of possible increased production and decreased water requirements. For this reason, a replicated field investigation was conducted to evaluate quantity and frequency of trickle, modified-furrow, and standard-furrow irrigations on the growth of cabbage, using a moderately saline water on a fine-textured soil. Trickle and modified-furrow irrigation were scheduled to supply various quantities of water based on ratios of the plant's estimated consumptive use at frequencies of 3, 6, and 12 days. Recorded data included yield, quality of production, and water-use efficiency. Results indicate that the consumptive-use requirement (38 cm of water in 1972) for high production of cabbage was about the same for all irrigation methods. Trickle and modified-furrow irrigation, however, did reduce furrow irrigation, showing that higher irrigation efficiencies can be attained with these new irrigation methods as opposed to conventional methods.

74:03F-155

### PREDICTING NITROGEN FERTILIZER REQUIREMENTS AFTER LAND LEVELING,

Thomas, J.R., Heilman, M.D., and Lyles, L.
United States Department of Agriculture, Weslaco, Texas.
Agronomy Journal, Vol. 66, No. 3, p 371-374, May-June, 1974. 5 fig, 4 tab, 6 ref.

Descriptors: *Fertility, Fertilization, Fertilizers, Land forming, Land reclamation, Land development, Crop response.

Reduced yields and nutrient-deficient crops on cut areas after land leveling are recognized problems. The objectives of this study were to determine if the variability in crop production between cut and fill areas of leveled fields could be minimized without overfertilization by adjusting the soils to a uniform level of available N based on the soil's capacity to supply N (N index) and to relate the N fertilizer requirement to the N index. Five leveling methods which resulted in the removal of different amounts of top soil were used. Soils from leveled and nonleveled areas were incubated and the soils' capacity to supply N were described by the regression model. With a 14-day incubation, the non-leveled soils supplied N at the rate of 174 kg/ha. Therefore, based on the leveled soils' ability to supply N in this time period, sufficient $NH_4NO_3$ fertilizer was applied to establish N levels of 174, 219, and 263 kg/ha. The leveled fields were cropped to forage sorghum. Dry matter forage yields, N uptake, and the growth rate during the first 19 days of growth were significantly related to the N index.

74:03F-156

### INTERACTIVE EFFECTS OF SALINITY AND FERTILITY ON YIELDS OF GRAINS AND VEGETABLES,

Bernstein, L., Francois, L.E. and Clark, R.A.
United States Department of Agriculture, Agricultural Research Service, Riverside, California.
Agronomy Journal, Vol. 66, No. 3, p 412-421, May-June, 1974. 7 fig, 2 tab, 27 ref.

Descriptors: *Salt tolerance, Salinity, Crop response, Fertilization, Saline soil, Corn, Wheat, Barley, Vegetable crops, Phosphate.

The salt tolerance of crops has usually been studied under optimal fertility conditions. The objectives of the present studies were to compare crop response to salinity when nutrients were limiting, adequate, or in excess to guide proper fertilization of saline soils and to determine whether additional fertilizer could restore yield losses caused by salinity. Corn, barley, and six vegetable crops were grown to maturity in large, outdoor sand cultures to study the interactive effects of salinity and nutrition. Increasing levels of phosphate (0.1 to 2.0 mM) aggravated salt injury in corn and decreased salt tolerance. Decreasing solution K from 2 to 0.4 meq/liter did not affect leaf K or yield of corn. Deficient levels of P or N did not consistently decrease salt tolerance of any of the crops studied, although the wheat and barley varieties showed erratic decreases in salt tolerance when N or P was deficient. When N or P was severely growth-limiting, salinity affected growth of some crops. Conversely, when salinity severely limited growth, nutritional responses of some crops decreased.

74:03F-157
SOME EFFECTS OF SUBIRRIGATION ON BENTGRASS DURING HEAT STRESS IN THE FIELD,
Krans, J.V. and Johnson, G.V.
Arizona University, Tucson, Department of Soils, Water and Engineering.
Agronomy Journal, Vol. 66, No. 4, p 526-530, July-August, 1974. 5 fig, 3 tab, 10 ref.

Descriptors: *Subsurface irrigation, Turf grasses, Fertilization, Root development, Temperature, Stress, Thermal stress, Soil, Soil investigations.

The management of bentgrass in the southwestern United States presents numerous problems to the grower because of the long period of high summer temperatures associated with this region. This study was conducted to determine if the adverse effects of heat stress could be alleviated by subirrigation. A field study was conducted to evaluate the merits of subirrigation on bentgrass during a 4-month period of heat stress. Effects were evaluated from clipping yields, chlorophyll content and root distribution. Three irrigation treatments were applied to artificial soils of washed mortar sand and a sand-soil mixture. Temperature adversely affected clipping yields and chlorophyll content during excessive heat stress (30 to 35 C) early in the summer. Clipping yields remained low, but color gradually darkened following the initial stress period. Sprinkle irrigation and subirrigation from a fluctuating water table resulted in similar yields, whereas subirrigation from a single stable water table at 30 cm produced significantly lower yields. Subirrigated plots also had significantly lower chlorophyll production than sprinkle-irrigated plots.

74:03F-158
RELATION OF SOYBEAN LEAF WATER POTENTIAL TO SOIL WATER POTENTIAL,
Brady, R.A., Powers, W.L., Stone, L.R., and Goltz, S.M.
Kansas State University, Manhattan.
Agronomy Journal, Vol. 66, No. 6, p 795-798, November-December, 1974. 5 fig, 1 tab, 12 ref.

Descriptors: Scheduling, Irrigation, Irrigation practices, Soybeans, Soil-water-plant relationships, Soil water, Moisture stress, Moisture tension.

Estimation of plant water potential is a possible aid in irrigation scheduling. This work examined the relation of maximum and minimum soybean leaf water potential to soil water potential. Maximum readings were taken near sunrise and minimum readings were taken between 1300 and 1500 CDT. Leaf water potentials were measured with a pressure chamber and soil water potentials were estimated using moisture release curves and volumetric soil moisture measurements made with a neutron probe.' Leaf water potentials decreased an average of 9 to 10 bars as a result of daily atmospheric evaporative demand during the vegetative stage. Soybean leaf water potential was as responsive to changes in soil water potential during the podding stage as during the vegetative stage. Data indicated the possibility of estimating soil water potential from early morning values of soybean leaf water potential.

74:03F-159
EFFECT OF PREPLANT-ONLY IRRIGATION ON COTTON YIELDS,
Bilbro, J.D.
United States Department of Agriculture, Agricultural Research Service, Southern Region, Lubbock, Texas.
Agronomy Journal, Vol. 66, No. 6, p 833-834, November-December, 1974. 1 fig, 4 ref.

Descriptors: *Plant growth, *Crop response, *Cotton, Irrigation practices, Planting management, Irrigation, Dry farming, Irrigation effects.

Irrigation practices for cotton are changing on the Texas High Plains because the irrigation water supply is declining. The objectives of this study were to calculate yield probabilities for cotton planted on both early and late dates and grown with only a preplant irrigation, and then to compare these yield probabilities with those previously calculated for dryland conditions. Yields from early and late plantings that had received only a preplant irrigation for the period 1960 through 1971 were used for calculating probabilities for various yield levels. The expected average yields (50% probability) of the early and late plantings of preplant-irrigated cotton are 530 and 503 kg/ha, respectively; and about 70% of the time the respective yields will differ by less than 50 kg/ha. Thus, the yield potential of preplant-irrigated cotton was not greatly affected by a wide range of planting dates. Also, 50% of the time preplant-irrigated land can be expected to yield about twice as much as comparable dryland and to vary much less in year-to-year yields.

74:03F-160
EFFECT OF IRRIGATION AND WATER-TABLE DEPTH ON CROP YEILDS,
Follett, R.F., Doering, E.J., Reichman, G.A., and Benz, L.C.
Northern Great Plains Research Center, Mandan, North Dakota.
Agronomy Journal, Vol. 66, No. 2, p 304-308, March-April 1974. 3 fig, 1 tab, 15 ref.

Descriptors: *Water management, *Drainage, *Corn, *Sugarbeets, *Alfalfa, Irrigation effects, Irrigation practices, Drainage practices.

The objective in this field study was to determine the most desirable combination of amount of irrigation and degree of drainage for production of corn, sugarbeets, and alfalfa grown on sandy soil over a declining water table. Irrigation was applied at weekly intervals at rates of either 0, 0.5, 1.0, or 1.5 times the water requirement of the crops as predicted by the modified Jensen-Haise equation. Irrigation amounts were applied in combination with shallow, medium, and deep drainage. In 1971 and 1972, early season depth to water table was 92 and 69 cm for the shallow drainage treatment, 166 and 145 cm for the medium, and 186 and 193 cm for the deep. Water-table declines were 94 and 96 cm during the 1971 and 1972 growing seasons, respectively, under all treatments. Corn was harvested at maturity, sugarbeets in mid-October, and alfalfa (three cuttings) at 1/10 bloom. Maximum yields of all crops occurred over the shallow water table; no yield response to irrigation was observed over the shallow water table.

74:03F-161
WATER RELATIONS OF COTTON. I. ROOT GROWTH AND WATER USE AS RELATED TO TOP GROWTH AND SOIL WATER CONTENT,
Taylor, H.M. and Klepper, B.
United States Department of Agriculture, Agricultural Research Service, Auburn, Alabama.
Agronomy Journal, Vol. 66, No. 4, p 584-588, July-August, 1974. 5 fig, 11 ref.

Descriptors: *Root development, *Root systems, Crop response, Moisture tension, Moisture availability, Soil-water-plant relationships, Cotton, Soil water.

Many experiments have evaluated the effects of decreasing soil water contents on top growth and yield of plants, but few experiments simultaneously have evaluated root growth. An experiment was conducted to determine the response of cotton roots and tops to decreasing soil water content. Plants were grown in rhizotron compartments with rainfall excluded by metal covers over the soil. Soil profile or irrigation schedule treatments provided different levels of soil and plant water potentials. Soil water content was determined with a neutron probe; rooting density, from measurements of roots on the glass viewing surface of each compartment. Plant water potential was determined with a pressure chamber apparatus, and top growth was evaluated by plant height. For conditions of this experiment, cotton root growth was correlated with decreases both in plant water potential and in soil water content.

74:03F-162
EFFECTS OF WATER MANAGEMENT AND SOIL AGGREGATION ON THE GROWTH AND NUTRIENT UPTAKE OF RICE,
Obermueller, A.J. and Mikkelsen, D.S.
Calfiornia University, Davis, Department of Agronomy and Range Science.
Agronomy Journal, Vol. 66, No. 5, p 627-632, September-October, 1974. 5 tab, 20 ref.

Descriptors: *Water management, Soil aggregates, Crop response, Nutrients, Nutrient requirements, Rice, Crop production, Flood irrigation, Surface irrigation, Irrigation practices, Root distribution.

Flooding is considered essential for the optimum growth and yield of rice (Oryza sativa). The benefits of flooding are not well understood, even though they have been associated with a reduction in soil moisture stress, alteration of root development, increased availability of plant nutrients, control of weeds, and a modified micro-climate environment. Since modification of soil aggregation may also influence some of the same plant responses as flooding, these effects were examined. The growth and development of rice, cv. 'Calrose,' was closely observed from seedling stage to maturity in a controlled greenhouse environment. At harvest the yield components, total yield of grain and straw, root production and distribution, and total uptake of N, P, K, Ca, Mg, Mn, An, Fe, and Si were determined. Rice plants grown under flooded conditions were superior to nonflooded plants except for the first 40 days after planting. Soil aggregation had little effect on the growth and development of flooded rice, but nonflooded rice was benefited by the puddled soil.

74:03F-163
WATER UPTAKE BY SEEDS AS AFFECTED BY WATER STRESS, CAPILLARY CONDUCTIVITY, AND SEED-SOIL WATER CONTACT. I. EXPERIMENTAL STUDY,
Hadas, A. and Russo, D.
Agricultural Research Organization, Bet Dagan, Israel, Division of Soil Physics, Volcani Center.
Agronomy Journal, Vol. 66, No. 5, p 643-647, September-October, 1974. 2 fig, 1 tab, 15 ref.

Descriptors: *Germination, *Seed treatment, Moisture stress, Seeds, Soil water, Soil-water-plant relationships, Hydraulic conductivity.

Imbibition and seed germination as affected by water potentials, hydraulic conductivity, and seed-water contact area were studied. Water potential effects were studied under perfect seed contact and unlimited hydraulic conductivity. Effects on imbibition and germination of hydraulic conductivity and seed-water contact were studied in an experimental setup in which separation between these factors was made possible while a very high water potential was maintained. The results show that low values of external water potential affect the rate of water uptake but not percent of germination. The rate of germination, however is affected as long as water potential is higher than a critical value that is species-specific. For a given seed-water contact area, any decrease in the hydraulic conductivity (or for a given conductivity, any reduction in contact area) reduced rates of water uptake and germination; total germination was not affected as long as the critical water potential was not reached.

74:03F-164
WATER UPTAKE BY SEEDS AS AFFECTED BY WATER STRESS, CAPILLARY CONDUCTIVITY, AND SEED-SOIL WATER CONTACT. II. ANALYSIS OF EXPERIMENTAL DATA,
Hadas, A. and Russo, D.
Agricultural Research Organization, Bet Dagan, Israel, Division of Soil Physics, Volcani Center.
Agronomy Journal, Vol. 66, No. 5, p 647-652, September-October, 1974. 9 fig, 1 tab, 16 ref, append.

Descriptors: *Germination, *Seed treatment, Seeds, Soil aggregates, Soil-water-plant relationships, Soil water, Moisture stress, Hydraulic conductivity.

Chickpea, pea and vetch seeds were germinated in pure, aerated water and in sand or aggregate fractions of various grain-size classes. These were either 1) packed in columns at various water contents kept constant by passing water at different rates equaling the conductivity of the least conductive layer in every column or 2) sown in aggregated soil at equilibrium with different matric water potentials. Water uptake rates, seed diameter, and time of germination were determined, and seed-soil water contact area was calculated. Water uptake data were analyzed to yield an approximation of the seed-soil water contact impedance by using a simplified model. The results show that the seed-soil water contact impedance increased as the wetted seed area and/or soil hydraulic conductivity decreased. The data also show that for optimal seed-soil water contact in aggregated soils, the mean aggregate size should be one-fifth to one-tenth of the seed's diameter. Possible application to field practice, such as seed-bed preparation, is discussed.

74:03F-165
VARIATION IN EFFECTIVENESS OF SUPPLEMENTAL IRRIGATION ON SWEET CORN YIELD COMPONENTS,
Andrew, R.H. and Weis, G.G.
Wisconsin University, Madison, Department of Agronomy.
Agronomy Journal, Vol. 66, No. 3, p 345-350, May-June, 1974. 1 fig, 7 tab, 14 ref.

Descriptors: *Supplemental irrigation, Crop response, Sweet corn, Irrigation efficiency, Moisture availability, Moisture tension.

Supplemental irrigation is of increasing importance in the production of processing sweet corn in the humid Midwest. However, wide variation exists for efficiency of irrigation as related to uniformity and quality as well as yield of this crop. The present study was planned to measure the response of major sweet corn yield components to, and their interaction with, irrigation level as related to genotype, plant competition, and season and to provide guidelines for optimum production practice. Six hybrids were grown at three populations (39,000, 49,000 and 59,000 plants/ha) under low and high irrigation levels on droughty sand in central Wisconsin over a 9-year period. Measurements were made of snapped weight, weight and number of usable husked ears, and percent of usuable ears expressed on a weight and a number basis.

74:03F-166
CRESTED WHEATGRASS YIELDS AS INFLUENCED BY WATER CONSERVATION PRACTICES,
Bleak, A.T. and Keller, W.
United States Department of Agriculture, Agricultural Research Service, Logan, Utah.
Agronomy Journal, Vol. 66, No. 2, p 326-328, March-April, 1974. 3 tab, 11 ref.

Descriptors: *Wheatgrasses, Crop response, Water conservation, Mulching, Fertilization, Evaporation, Evaporation control.

Evaporation of water from the soil surface is a major economic loss to the western United States, because water is the primary limiting factor in plant growth on arid and semiarid rangelands. 'Nordan' crested wheatgrass was planted in rows 1.1 m apart; the effect on total herbage yield of a gravel mulch, a sheet metal "mulch," close rows of grass, and cereal grain seeded between the grass rows was determined for a 2-year period. Some treatments received different rates of N fertilizer. Sheet metal between the rows, covering 86% of the land surface, increased mean 2-year yield about 112% over clean cultivation (check). A gravel mulch 1.5 cm deep increased mean yield about 16%. Close rows of grass and cereal grain between the grass rows also increased total yield. Benefit from nitrogen at 22, 44, or 66 kg/ha per year was minor. Benefit from the mulches was greater the second year than the first.

74:03F-167
EFFECT OF AN ASPHALT BARRIER ON WATER STORAGE AND DROUGHT PROBABILITY,
Palta, J.P. and Blake, G.R.
Minnesota University, St. Paul, Department of Soil Science.
Agronomy Journal, Vol. 66, No. 2, p 209-212, March-April, 1974. 3 fig, 2 tab, 7 ref.

Descriptors: *Asphalt, *Barriers, Droughts, Drought resistance, Available water, Soil water, Soil water movement, Moisture availability, Moisture stress.

Field measurements of water redistribution after infiltration were made on two sandy soils with and without asphalt barriers at a 55 cm depth to determine the barrier effect on soil water potential gradients and on water retention at various times. Estimates of the effect of the barrier on seasonal drought severity and on movement of water to horizons below the barrier were made on one of the soils. Soil water potential gradients and the volumetric water content at different depths were nearly the same for barrier and non-barrier plots on Hubbard loamy coarse sand because a coarse sand-gravel layer between the 25 and 50-cm soil depths acts as a water barrier. After 96 hours drainage, suctions in Zimmerman fine sand reached 31 cm of water just above the barrier and 61 cm at the same depth without barrier. Available water to barrier depth was increased from 2.9 cm to 7.5 cm by the barrier.

74:03F-168
PERFORMANCE OF RICE VARIETIES IN A HIGHLY SALINE SODIC SOIL AS INFLUENCED BY PLANT POPULATION,
Dargan, K.S., Abrol, I.P. and Bhumbla, D.R.
Central Soil Salinity Research Institute, Karnal, Haryana, India, Division of Soils and Agronomy.
Agronomy Journal, Vol. 66, No. 2, p 279-280, March-April, 1974. 2 tab, 3 ref.

*Salinity, *Saline soil, *Crop response, *Rice, *Plant populations, Germination, Alkalinity, Reclamation.

It is generally recognized that increased initial plant population or increased seeding rate in saline sodic soils would compensate for decreased germination and seeding mortality. However, there is little or no experimental evidence of the gains obtained from such a practice. In present investigation, the performance of seven rice varieties at three plant populations in a highly saline sodic soil was studied in the field at the Central Soil Salinity Research Institute, Karnal, India. Varieties tested were the tall indica types 'Jhona 349', 'Jhona 351,' 'Basmati 217', and 'Basmati 370' and the semi-dwarf types 'IR 8,' 'IR6-68' and 'Jaya.' Plant populations used were 2, 4, and 6 transplants/hill. Variety IR 8-68, a local selection from IR 8, with 6 transplants/hill gave the significantly highest grain yield at 57.33 quintals/ha. Variety IR 8 at 6 transplants/hill and Jhona 349 at 4 transplants/hill yielded next in order. Increase in plant population from 2 to 4 and 6 transplants/hill resulted in significantly higher grain yield in all varieties except Jhona 349 where there was a decrease at 6 transplants/hill. Increased yield resulted from increased survival of hills and greater number of panicle-bearing tillers per hill.

74:03F-169
EVAPOTRANSPIRATION BY SUBIRRIGATED ALFALFA AND PASTURE IN THE EAST CENTRAL GREAT PLAINS,
Blad, B.L. and Rosenberg, N.J.
Nebraska University, Lincoln, Department of Horticulture and Forestry and Conservation and Survey Division.
Agronomy Journal, Vol. 66, No. 2, p 248-252, March-April, 1974. 4 fig, 4 tab, 14 ref.

Descriptors: *Evapotranspiration, Subsurface irrigation, Alfalfa, Pastures, Irrigation practices, Irrigation, Nebraska, Latent heat, Advection, Energy budget.

Descriptors: *Evapotranspiration, Subsurface irrigation, Alfalfa, Pastures, Irrigation practices, Irrigation, Nebraska, Latent heat, Advection, Energy budget.

Evapotranspiration (ET) rates from subirrigated alfalfa pasture were obtained to provide an estimation of the upper and lower limits of water demand for crops growing in climatic regions characterized by strong advection of sensible heat. Results of this study showed that ET rates were 20 to 25% lower in pasture than in alfalfa. These differences are much larger than any previously reported in the literature. Advected sensible heat supplied about 20% of the total energy consumed in the latent heat flux (LE) from alfalfa for the entire study and as much as 40% on certain days. In the pasture, however, with few exceptions, sensible heat was generated rather than consumed.

74:03F-170
COMPARISON OF FOG IRRIGATION WITH SURFACE IRRIGATION IN CORN PRODUCTION,
Doss, B.D.
United States Department of Agriculture, Agricultural Research Service, Auburn, Alabama.
Agronomy Journal, Vol. 66, No. 1, p 105-107, January-February, 1974. 3 tab, 8 ref.

Descriptors: *Mist irrigation, *Furrow irrigation, *Surface irrigation, Crop response, Corn, Irrigation systems, Irrigation practices, Irrigation effects.

Water stress by plants during silking and ear development often affects the yield of corn. Water stress sometimes occurs during midday even with a relatively high soil water content. Field experiments were conducted for 3 years to determine the effect of fogging or mist irrigation alone, surface irrigation alone, and fogging plus surface irrigation on plant characteristics and grain and stover yields of corn. Plants received mist irrigation daily from 1000 until 1600 during silking and ear development. Surface irrigation was applied to maintain soil water at or above the 50% available level (0.8 bar) in the surface 60 cm of soil. An increase in grain yield was obtained in each of the 3 years with surface irrigation and in 2 of the 3 years with fogging or mist irrigation, but fogging in addition to surface irrigation did not increase grain yields above those for surface irrigation alone. Average grain yields for the 3 years were 6,200, 8,400, 9,200, and 9,500 kg/ha for no irrigation, fogging, surface, and fogging plus surface irrigation, respectively.

74:03F-171
CHOICE OF IRRIGATION TIMING INDICATOR FOR NARROW ROW COTTON,
Bordovsky, D.G., Jordan, W.R., Hiler, E.A., and Howell, T.A.
Kansas Agricultural Experiment Station, Colby Branch Station, Colby.
Agronomy Journal, Vol. 66, No. 1, p 88-91, January-February, 1974. 4 fig, 3 tab, 17 ref.

Descriptors: *Soil moisture, Soil-water-plant relationships, Water management, Irrigation efficiency, Irrigation practices, Irrigation, Soil water potential.

This irrigation study was undertaken to compare water use efficiencies (WUE) resulting from three methods of timing water applications on narrow-row cotton. Irrigation timing during the 1971 and 1972 growing seasons was accomplished using the soil water potential (SWP)- fixed level, leaf water potential (LWP)-fixed level, and stress day index (SDI)-variable level of LWP, based on crop sensitivities, as indicators. Specific levels of each indicator were selected so that nearly identical yields would result for all three timing indicators, thus making possible the valid comparison of WUE. With the SWP indicator as a basis for comparison, higher WUE were obtained with the LWP and SDI indicators in both years. At a plant population of 150,000 plants/ha average increases in WUE (seed cotton yield divided by irrigation plus rainfall amounts) were 17 and 38% for the LWP and SDI indicators, respectively. These results demonstrate that significant benefits in stretching irrigation water supplies are possible when using plant-based measurements and when plant sensitivities at different growth stages are quantitatively considered in timing irrigations.

74:03F-172
EVALUATION OF AN OVER-EXTENDED SPRINKLER IRRIGATION SYSTEM,
Korven, H.C. and Wiens, J.K.
Canadian Society of Agricultural Engineers, Research Station, Swift Current, Saskatchewan S9H 3X2.
Journal of Canadian Society of Agricultural Engineering, Vol. 16, No. 2, p 51-57, December 1974. 4 fig, 6 tab, 7 ref.

Descriptors: *Sprinkler irrigation, Irrigation practices, Irrigation systems, Evaluation, Consumptive use, Cost analysis.

Maximum production under irrigation requires a system with the capacity to meet the peak water requirements of the plant. Surface irrigation systems, particularly the border dyke method fed by gravity water, are designed and operated so that elapsed time required to irrigate a field (irrigation cycle) is much shorter than the elapsed time between irrigations (irrigation interval). Sprinkler irrigation systems, however, are designed and operated so that most, if not all, of the irrigation interval is used for the irrigation cycle. The main reason for this is one of economics. The cost of the system is decreased as more of the available irrigating time is used for irrigating. The purpose of this study was to examine the yields and economic ramifications of using a sprinkler irrigation system over a larger area than that determined by the normal criterion of designing the system to meet peak water requirements.

74:03F-173
THE RELATIONSHIP BETWEEN SOLAR RADIATION, SOIL WATER, AND WATER POTENTIAL OF EARS OF WHEAT,
Dougherty, C.T.
Department of Plant Science, Lincoln College, Canterbury, New Zealand.
New Zealand Journal of Agricultural Research, Vol. 17, No. 4, p 459-463, November 1974. 2 fig, 2 tab, 11 ref.

Descriptors: *Soil water, *Moisture tension, *Solar radiation, Wheat, Crop

Water potentials of ears of 'Kopara' wheat grown in the field with or without irrigation were measured by pressure bomb between 0900 and 1000 h and related to soil water and solar radiation. Water potentials of ears from irrigated wheat ranged from -2 to -14 bars, and from -8 to -27 bars in ears from non-irrigated plots. Ear water potentials between 0900 and 1000 h were related to soil water percentage and mean solar radiation received between 0700 and 0800 h.

74:03F-174
AN ANALYSIS OF A NITROGEN-INDUCED DEPRESSION OF YIELD IN IRRIGATED 'KOPARA' WHEAT,
Dougherty, C.T. and Langer, R.H.M.
Department of Plant Science, Lincoln College, New Zealand.
New Zealand Journal of Agricultural Research, Vol. 17, No. 3, p 325-323, August 1974. 2 fig, 7 tab, 20 ref.

Descriptors: *Fertilization, *Fertilizers, Moisture tension, Nitrogen, Wheat, Crop response, Plant growth.

Heavy applications of nitrogen fertilizer (200 kg/ha) applied in early spring to wheat on a Wakanui silt loam, in which irrigation was used to maintain soil-water levels above -0.5 bar, depressed grain yield by 30%. Poor grain set was the main cause of the low yields, but mean grain weights were also reduced. Analysis of data indicated that grain set was probably restricted by the availability of carbohydrate during the critical pre-anthesis period of floret development.

74:03F-175
EFFECTS OF IRRIGATION AND FERTILIZER ON THE YIELDS OF 'ARAWA', 'AOTEA', AND 'KARAMU' WHEATS,
Dougherty, C.T., Scott, W.R., Langer, R.H.M. and Meijer, G.
Department of Plant Science, Lincoln College, Canterbury, New Zealand.

New Zealand Journal of Agricultural Research, Vol. 17, No. 2, May 1974. 3 fig, 5 tab, 30 ref.

Descriptors: *Fertilization, *Fertilizers, *Irrigation practices, Wheat, Irrigation effects, Plant growth, Agronomic crops.

Grain yields of 'Aotea', 'Arawa', and 'Karamu' wheats were depressed by irrigation during early stages of reproductive development which reduced the number of grains per spikelet and slowed the rate of reproductive development. Nitrogen fertilizer increased the ear population at harvest but had little effect on the dry weight or leaf area of the tillers during the critical pre-anthesis stage or on the mean values of the components of yield of the ears. There were no interactions between fertilizer and irrigation treatments. 'Karamu', a Mexican semi-dwarf, was similar to the New Zealand-bred wheats except that it had slightly more spiklelets per ear and grains per spikelet, but it had smaller grains. An antitranspirant applied to irrigated wheat had no effect on any of the components of grain or straw yield. Responses were interpreted on the basis that pre-anthesis assimilate levels were modified by agronomic treatments and affected grain set.

74:03F-176
PREDICTION OF PLANT RESPONSE TO FERTILIZERS BY MEANS OF SOIL TESTS,
Grigg, J.L. and Stephen, R.C.
Invermay Agricultural Research Centre and Field Research Section, Ministry of Agriculture and Fisheries, Christchurch, New Zealand.
New Zealand Journal of Agricultural Research, Vol. 17, No. 1, p 31-40, February 1974. 1 fig, 7 tab, 15 ref.

Descriptors: *Fertilizers, *Fertilization, *Crop response, *Soil tests, Wheat, Phosphate, Crop production, Plant growth.

Data from 82 rates-of-fertilizer trials on wheat, in which double superphosphate was the source of phosphate, were used to evaluate the predictability of grain yield responses from soil-test measurements. Yield data were reduced to single values for correlations with soil phosphorus tests by calculating (a) relative yields % and (b) the first principal components of the yield responses. Regression of these parameters on values from eight different soil tests, using a quadratic model in the square root scale, showed that the Olsen soil test modified to 16-h extraction and a soil: solution ratio of 2.2 ml: 100 ml accounted for more variation than other soil tests examined. The correlations with soil tests were closer for the relative yields than for the first principal components.

74:03F-177
WATER SHORTAGES AND AGRICULTURE: SOME RESPONSES,
Gates, C.T.
Division of Plant Industry, Canberra City, Australia.
The Journal of the Australian Institute of Agricultural Science, Vol. 40, No. 2, p. 121-142, June 1974. 13 fig, 3 tab, 62 ref.

Descriptors: *Water shortages, *Agriculture, *Australia, Crop response, Soil water, Moisture tension, Fertilization, Root development.

Water shortages of varying intensities impose a prime limitation on Australian agriculture, resulting not only in poor plant yield from droughting, but also engendering such economic uncertainty that farmers restrict their programs. However, this situation may be alleviated by practical consideration of certain concepts which arise from existing fundamental knowledge. It is the purpose of this article to bring together the diverse fields of knowledge containing practical information relevant to the problem of water shortage and by analyzing them in sufficient detail reach some useful conclusions.

74:03F-178
DRIPPER SPACINGS FOR UNIFORM IRRIGATION COVERAGE WITH CONTINUOUS TRICKLE IRRIGATION,
Stevenson, D.S.
Agriculture Canada, Research Station, Summerland, B.C.
International Commission on Irrigation and Drainage, p 17 & 25, July 1974
1 tab.

Descriptors: *Irrigation practices, *Irrigation design, *Irrigation efficiency, Irrigation systems.

Trickle irrigation depends on a soil's ability to transfer water horizontally, a radical departure from sprinkler technology which is based on uniform application of water via the delivery equipment itself. It must be recognized that application of all the water a plant uses each day to some arbitrary land area somewhere around each plant, such as a tree or vine, will not produce uniform, efficient and adequate irrigation except by chance. The lateral transfer of water while it moves vertically in each soil must be the basis upon which application per unit time per unit area is established.

74:03F-179
THE "MULTIVALVE" IRRIGATION METHOD,
Karamanos, A.J.
International Commission on Irrigation and Drainage, p 42-59, January 1974.
9 fig, 19 tab.

Descriptors: *Irrigation systems, *Irrigation engineering, Irrigation, Irrigation practices, Crop response, Equipment.

The "multivalve irrigation" is a modification of the drip or trickle irrigation method, which comprises the use of the "multivalve", first invented and described by Mr. A.G. Petzetakis at the Seventh European Regional Conference of the I.C.I.D. held at Aix-en-Provence in 1971. The "multivalve" is a bronze head containing 32 capillary polyethylene tubes. The ends of each tube are put into the soil at different spacings. The first experiment on this new irrigation method was carried out during the summer period 1972. The purpose of the experiment was to determine the most suitable distance for placing the tubes with regard to the growth and productivity of the plants and to the financial aspect of the method. The spacings used were 50 cm x 50 cm, 75 cm x 75 cm, 100 cm x 100 cm and 150 cm x 150 cm. At the same time the results of the multivalve system were compared with those obtained from a control plot irrigated by furrows.

74:03F-180
THE VALUE OF VEGETATION FOR CONSERVATION II. M1 MOTORWAY AREA,
Helliwell, D.R.
Merlewood Research Station, Grange-over-Sands, Lancashire, England.
Journal of Environmental Management, Vol. 2, No. 1, p 75-78, January 1974. 1 fig, 1 ref.

Descriptors: *Vegetation effects, Vegetation, Conservation, Plant populations.

A list of plant species occurring along 175 miles (282 km) of motorway embankment has been used in an attempt to compare the conservation "value" of this vegetation with four other areas of vegetation, but it is concluded that such a comparison is not possible.

74:03F-181
THE VALUE OF VEGETATION FOR CONSERVATION I. FOUR LAND AREAS IN BRITAIN,
Helliwell, D.R.
Merlewood Research Station, Grange-over-Sands, Lancashire, England.
Journal of Environmental Management, Vol. 2, No. 1, p 51-74, January 1974.
1 fig, 4 tab, 5 ref, 1 append.

Descriptors: *Vegetation effects, Vegetation, Conservation, Plant population

Lists of plant species and their relative frequency have been used, in conjunction with the "Atlas of the British Flora", to compare the conservation "value" of the vegetation on four different areas of land in Britain. A wide range of assumptions as to the weighting to be given to the rarity of species gives very similar results in each case.

74:03F-182
EFFECTS OF TIME TAKEN TO APPLY AN IRRIGATION ON SEASONAL IRRIGATION REQUIREMENTS,
Sly, W.K. and Wilcox, J.C.
Chemistry and Biology Research Institute, Canada Department of Agriculture, Ottawa, Canada.
Journal of the Canadian Society of Agricultural Engineering, Vol. 16, No. 2, p. 82-85, December 1974. 3 tab, 11 ref.

Descriptors: *Scheduling, Irrigation practices, Consumptive use, Irrigation systems, Timing, Canada, Soil water, Water consumption.

Daily climatic data for the 30 year period 1931-60 were used in two routine scheduling procedures to estimate seasonal irrigation requirements for soils of different water-holding capacities at six selected localities in British Columbia. The first procedure, described in detail by Wilcox and Sly, closely follows the practices recommended for the Okanagan Valley. Four days are required to apply each 2.54 centimeters of water to the field. In the second procedure, equipment was assumed to be such that water would be applied to the entire field at the same time. The same basic principles are followed as with the first procedure, but adjustments were made to ensure that the same availability of soil water to plants prevailed under both methods. Differences in the irrigation requirements resulted from these adjustments. In every case, and for each water-holding capacity of the soil and each climatic condition, less water was required under the second scheduling method.

74:03F-183
NITRATE UPTAKE EFFECTIVENESS OF FOUR PLANT SPECIES,
Warncke, D.D. and Barber, S.A.
Purdue University, West Lafayette, Indiana.
Journal of Environmental Quality, Vol. 3, No. 1, p 28-30, January-March, 1974. 2 tab, 5 ref.

Descriptors: *Fertilization, *Fertilizers, *Nitrogen, Crop response, Plant growth, Corn, Soybeans, Bromegrass, Nitrates.

Little information is available on the characteristics of plant roots that determine their effectiveness in nitrate uptake. The effectiveness of nitrate uptake of corn, soybeans, sorghum, and bromegrass intact roots were investigated in nutrient solution culture. The maximum uptake rate per centimeter of root for corn occurred at 10 mM, for sorghum at 2.4 mM, and for bromegrass at 0.8 mM. Increasing the nitrate level above 1.0 mM did not increase the growth rate during the first 3 weeks for any of these species. The results of this research indicate that the roots of the species investigated absorbed nitrate of maximum rates from relatively low nitrate concentrations provided the concentration was maintained. Also, the degree of reduction in nitrate level where nitrate in solution was not maintained indicated that these plant roots had the absorptive capacity to reduce solution nitrate to concentrations of 4 micro-M or less.

74:03F-184
NITROGEN-15 VARIATIONS IN FERTILIZER NITROGEN,
Freyer, H.D. and Aly, A.I.M.
Institute of Physical Chemistry, Nuclear Research Center Juelich, Federal Republic of Germany.
Journal of Environmental Quality, Vol. 3, No. 4, p 405-406, October-December, 1974. 1 tab, 11 ref.

Descriptors: *Fertilizers, *Nitrogen, *Ammonium compounds.

Nitrogen-15 concentrations of some commonly used nitrogen fertilizers are measured. Ammonium-nitrogen has lower and nitrate-nitrogen has higher 15(N) concentrations than atmospheric nitrogen.

# Section XIII

## WATER QUANTITY MANAGEMENT AND CONTROL

### CONTROL OF WATER ON THE SURFACE (Group 04A)

74:04A-001
DRAINAGE SYSTEM DESIGN AND ANALYSIS BY COMPUTER,
Renner, D.M. and Mueller, C.C.
Soil Conservation Service, Portland, Oregon.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 100, No. IR3, Proceedings paper No. 10801, p 255-265, September 1974. 8 fig, 1 tab, 11 ref.

Descriptors: *Drainage systems, *Subsurface drainage, *Design, *Computer programs, *Equations, *Irrigated land, Tile drains, Water table, Costs, Depth, Hydraulic conductivity, Washington, Systems analysis.

The conditions needed for the theoretical mathematical solution in the design of subsurface drainage systems are usually hard to find in the field. An optimum system design cannot be obtained without knowledge of the correct inputs to the drainage design equation. Two programs are presented for using the computer to design subsurface drainage systems for irrigated areas. The first calculates drain spacings using the Dumm, Moody, and Tapp nonsteady-state transient flow method, which provides close correlation between theory and practice. The second program provides drainage system layouts in an area requiring drainage for any specified drain spacing and drain depth. Using these two programs, all input parameters can be investigated and the effect of their variance on both drain spacing and system cost can be found. Thus, a sensitivity relationship between the drain spacing and system layout, and the parameters used in calculating the spacing, can be defined.

74:04A-002
OPTIMAL CONTROL OF MULTIUNIT INTER-BASIN WATER RESOURCE SYSTEMS,
Takeuchi, K. and Moreau, D.H.
Tokyo Institute of Technology, Japan, Department of Civil Engineering.
Water Resources Research, Vol. 10, No. 3, p 407-414, June 1974. 6 fig, 2 tab, 28 ref.

Descriptors: *Multiple-purpose projects, *River basin development, *Reservoir operation, *Linear programming, *Dynamic programming, Stochastic processes, Algorithms, Simulation analysis, Equations, Optimization, Economic efficiency, Reservoir storage, Reservoir releases, Inflow, Streamflow, Methodology, Decision making, North Carolina, Mathematical models, Systems analysis.

A method is presented for finding optimal operating policies for a multireservoir water resource system that extends over two river basins and serves multiple demands. The method has been developed and tested for one of several water resource systems proposed for further development in the urbanizing Piedmont Triad region of North Carolina. Monthly operating decisions are given by solutions of a piecewise linear programming problem; the objective function consists of two parts: immediate economic losses within the month and the expected present value of future losses as a function of end-of-month storage levels in the reservoirs. The latter function is estimated by imbedding the linear programming problem in a stochastic dynamic programming problem. An approximate solution technique for the larger problem is described, and computational experience is reported. The approximate solution technique involves the use of simulation in a recursive algorithm. Simulation is used also to test the derived policy on the 40 years of actual streamflow data that exist in the case study area.

74:04A-003
OPTIMAL DESIGN AND OPERATION OF WATER DISTRIBUTION SYSTEMS,
Shamir, U.
Thomas J. Watson Research Center, Yorktown Heights, New York.
Water Resources Research, Vol. 10, No. 1, p 27-36, February 1974. 1 fig, 2 tab, 31 ref.

Descriptors: *Water distribution(Applied), *Design, *Operation and maintenance, *Methodology, Economics, Constraints, Performance, Physical properties, Optimization, Pipes, Flow, Reservoirs, Water levels, Hydraulics, Costs, Computer programs, Mathematical models, Systems analysis, Equation.

A methodology is developed for optimal design and/or operation of a water distribution system that is to operate under one or several loading conditions. Decision variables may be design variables, such as pipe diameters, or control variables, such as heads and flows. The general formulation considers the cost of the design and the cost of operating the system. The objective function may include the initial cost of the design, the cost of operation, the physical measures of performance, and the penalties for violating constraints. Constraints may be imposed on the decision variables and on the performance of the system under each loading. The model for the flow problem is based on node equations. Flow solutions are obtained by a modified Newton-Raphson method employing sparse matrix techniques. Optimization is obtained by a combination of the generalized reduced gradient and penalty methods. Implementation in a computer program and its use on a test problem in both batch and time-sharing modes are described, and it is concluded that the method is computationally feasible. The many different ways in which it can be used to analyze, design and operate water distribution systems are outlined.

74:04A-004
MODIFICATION OF ROUTED STREAMFLOW BY CHANNEL LOSS AND BASE FLOW,
Moench, A.F., Sauer, V.B. and Jennings, M.E.
Geological Survey, Denver, Colorado.
Water Resources Research, Vol. 10, No. 5, p 963-968, October 1974. 8 fig, 1 tab, 17 ref.

Descriptors: *Routing, *Base flow, *Water loss, *Hydrograph analysis, Computer programs, Mathematical models, *Oklahoma, Surface-groundwater relationships, Open channel flow, Stage-discharge relations.

The convolution integral was used to compute continuous variations in channel loss and base flow that result from a reservoir release on the North Canadian River in central Oklahoma. The open channel flow hydrograph was routed by using the unit response method and then modified for interaction with the aquifer. Stream losses and gains were evaluated from the arbitrary fluctuations in stream stage by using average values of aquifer parameters. In spite of gross simplification pertaining to the nature of the groundwater system, good agreement with the actual flow hydrograph was obtained.

74:04A-005
EFFECTS OF INUNDATION PERIOD ON SEEDLING GROWTH,
Howell, T.A. and Hiler, E.A.
Texas A&M University, College Station, Agricultural Engineering Department.

Transactions of the American Society of Agricultural Engineers, Vol. 17, No. 2, p 286-288 & 294, March-April 1974. 5 fig, 1 tab, 11 ref.

Descriptors: *Drainage effects, *Drainage practices, Drainage, Crop response, Corn, Cotton, Grain sorghum, Lysimeters, Aeration.

In considering the necessary steps for proper agricultural drainage design, the logical first step is the determination of the crop's drainage requirement. The purpose of this paper was to present and evaluate findings concerning effects of inundation period on soil oxygen diffusion rates and crop response during the seedling growth of four selected plant species. Corn, cotton, grain sorghum, and southern pea plants were grown for 30 days in field lysimeters which were inundated for periods of 2, 5, and 8 days, starting approximately 1 week after emergence. Undisturbed soil cores which were 90 cm in diameter and 180 cm deep made up the lysimeters. Rainfall was kept off the lysimeters with an automated shelter system. Oxygen diffusion rate and soil water pressure potential measurements were made in the crop root zone on a regular basis. Primary crop response measurements included crop height during the growing season and dry matter yield at the end of the growth period. Water was added at the soil surface to maintain the soil water pressure potential in the crop root zone between -10 and - 20 centibars, and hence prevent crop water stress, during periods when no flooding occurred.

74:04A-006
USE OF DRAINAGE WELLS,
Ham, H.H.
Bureau of Reclamation, U.S. Department of the Interior, Denver, Colorado.
Presented at 1974 Winter Meeting of the American Society of Agricultural Engineers, December 10-13, 1974. Chicago, Illinois. 8 fig, 12 ref.

Descriptors: *Drainage wells, Drainage systems, Drainage practices, Drainage engineering, Flow systems, Transmissivity.

Wells are often viewed as an alternative to drains for agricultural subsurface drainage. Where subsurface and other conditions are favorable, wells may offer advantages despite hydraulic and other shortcomings. However, areas of such favorable conditions are limited. Furthermore, improper use of wells may jeopardize long-term productivity of the land. Use of wells for agricultural subsurface drainage may appear advantageous but should be approached with caution unless investigations have determined that conditions are favorable.

74:04A-007
THE FATE OF NITRATE IN LAKE SEDIMENT COLUMNS,
Chen, R.L. and Keeney, D.R.
Wisconsin University, Madison, Department of Soil Science.
Water Resources Bulletin, Vol. 10, No. 6, p 1162-1172, December, 1974.

Descriptors: Sedimentation, Nitrogen cycle, Nitrogen, Denitrification, Seepage, Oxidation-reduction potential.

To investigate the magnitude of denitrification and assimilatory nitrate reduction as these reactions relate to the fate of nitrate reaching sediments via groundwater seepage, undisturbed core samples of sediments (40 cm length) from two lakes (Mendota and Tomahawk) were leached from the bottom (at 1.4 cm/day) with a solution of 15N-nitrate (10 mg N/liter). The sediment columns were fitted with Pt electrodes to measure the oxidation-reduction (Eh) potential. While leaching removed considerable ammonium-N and soluble organic N, essentially no 15N had passed through the columns by 50 days. The Eh readings indicated that denitrification was occurring in the lower portions of the columns. The 15N distribution of the sediment N after 50 days showed that about 15 to 26% of the added nitrate-N was converted to organic N and ammonium N. The data show that denitrification can be a significant N sink in seepage lakes.

74:04A-008
IRRIGATION IN THE UNITED STATES; THE SITUATION TODAY,
Warme, W.E.
International Commission on Irrigation and Drainage, p 12-16, July 1974.

Descriptors: *Irrigation, Irrigation effects, Irrigation programs, Agriculture, United States.

Irrigation supports the agriculture of the semi-arid and arid western United States. Agriculture is the cominant industry of the region. Irrigation is practiced increasingly in the more humid states, as well, but among them, except in Florida, Arkansas and Louisiana, irrigation is not given much attention as a factor influencing farm production. The situation in the United States today is that irrigation is a western operation of critical importance in the production of food and fiber. Irrigated agriculture is the foundation of the economy of the western states.

74:04A-009
HYDROCHEMISTRY OF THE ATHABASCA AND NORTH SASKATCHEWAN RIVERS IN THE ROCKY MOUNTAINS OF CANADA,
Drake, J.J. and Ford, D.C.
McGill University, Montreal, Quebec, Canada, Department of Geography.
Water Resources Research, Vol. 10, No. 6, p 1192-1198, December 1974. 4 fig, 3 tab, 12 ref.
(See 74:02E-003)

74:04A-010
SIMULATION OF GAMMA-DISTRIBUTED FIRST-ORDER MARKOV CHAIN,
Klemes, V. and Boruvka, L.
Hydrology Research Division, Ottowa, Ontario, Canada, Department of the Environment.
Water Resources Research, Vol. 10, No. 1, p 87-91, February, 1974. 1 fig, 1 tab, 9 ref.

Descriptors: *Markov processes, Simulation analysis, Hydrology, Mathematical studies, Mathematics.

Simulation of a serially correlated series with a given marginal distribution is one of the important prerequisites of synthetic hydrology and of its applications to analysis of water resource systems. The problem has, however, no fully satisfactory solution because of the difficulties in defining other than normal multivariate distributions. The gamma-distributed first-order Markov chain (TIMC) is one of the most useful models of this category, since marginal distributions of many hydrologic variables can be approximated satisfactorily by the gamma distribution, and the limited understanding of the sequential behavior of the process combined with the smallness of available data samples often does not warrant models more sophisticated than the first-order Markov chain.

74:04A-011
AGRICULTURAL WASTE MANAGEMENT,
Committee on Agricultural Waste Management of the Environmental Engineering Division.
Journal of the Environmental Engineering Division, Vol. 100, No. EE1, p 1-6, February, 1974. 1 fig.

Descriptors: *Return flow, *Waste water (pollution), Wastes, Agriculture, Irrigation, Irrigation practices, Irrigation effects.

Since the practice of irrigation has detrimental effects on water quality, irrigation return flows must be considered an agricultural waste. The major water quality problem is increased salt concentration in the return flows as a result of the pickup of minerals from the soils and the loss of water through evapotranspiration. Irrigated agriculture is the largest consumer of our water resources, and return flows constitute a large portion of the flow in many western streams. Salt concentrated by evapotranspiration must be leached from the root zone to continue crop production. This necessity of leaching to maintain a salt balance concentrates salts in the return flows and causes damage downstream.

74:04A-012
EVALUATION OF SURFACE WATER RESOURCES FROM MACHINE-PROCESSING OF ERTS MULTISPECTRAL DATA,
Mausel, P.W., Todd, W.J., Baumgardner, M.F., Mitchell, R.A., and Cook, J.P.
Indiana State University, Terre Haute
Journal of Environmental Quality, Vol. 3, No. 4, p 316-321, October-December, 1974. 5 fig, 1 tab.
(See 74:07B-008)

## WATER QUANTITY MANAGEMENT AND CONTROL

### GROUNDWATER MANAGEMENT (Group 04B)

74:04B-001
EXTENSIVE PUMPING FROM UNCONFINED AQUIFERS,
Rushton, K.R.
Birmingham University, England, Department of Civil Engineering.
Water Resources Bulletin, Vol. 10, No. 1, p 32-41, February 1974. 5 fig, 2 tab, 5 ref.

Descriptors: Water resources development, *Water yield, *Groundwater movement, *Numerical analysis, Drawdown, *Withdrawal, Mathematical models, Water table, Recharge, *Pumping.

Heavy pumping of an aquifer to remove a significant proportion of the stored water is considered using a numerical method which permits the analysis of radial flow to a well in an unconfined aquifer and allows for the reduction in the saturated depth. The analysis is restricted to extensive unconfined aquifers of constant thickness which are initially full of water with wells positioned on a square grid. When the aquifer is recharged with the recharge equaling the discharge, it is possible that a steady state will be reached with the heads remaining constant with time. Withdrawal of a large proportion of the available water from an unconfined aquifer requires carefully controlled pumping. If the discharge rate is too high, the pump will quickly run dry and only a very small proportion of the water will be withdrawn.

74:04B-002
ANALYTICAL MODEL FOR MANAGEMENT OF ALLUVIAL AQUIFERS,
Qazi, R. and Danielson, J.
Colorado Department of Natural Resources, Denver, Division of Water Resources, Planning and Investigations.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 100, No. IR2, Paper no 10627, p 143-152, June 1974. 5 fig, 1 tab, 4 ref.

Descriptors: *Alluvial aquifers, *Wells, *Pumping, *Water management(Applied), *Simulation analysis, *Computer models, Groundwater, Flow, Water table, Reservoir storage, Recharge, Rivers, Surface waters, Conjunctive use, Water delivery, Water supply, Damages, Drawdown, Canals, Irrigation water, Municipal water, Computer programs, Equations, Evaluation, Systems analysis, *Colorado.

Under the doctrine of prior appropriation, the recent inclusion of wells in the existing priority system of water rights in Colorado has created new problems for water management in tributary alluvial aquifers. Irrigation and municipal wells, generally subordinate to surface water rights on a river, are subject to complete shut down if they cannot compensate for the river depletion due to pumping; to shut these wells off could mean economic disaster to large rural areas in Colorado. Therefore, augmentation plans have been accepted by the Division of Water Resources whereby well owners must provide for river depletion in both time and space either by recharge operations or by direct deliveries to the river from acquired surface water. To evaluate these plans, an analytical approach using computer simulation has been derived to estimate the change in storage of the groundwater and the rate and amount of movement of water to and from the river. The model, presented in detail, can provide quick estimates of the volumetric movements and the fluctuation of the water table due to any combination of wells, recharge lines, or pit operations in an alluvial (unconfined) aquifer. Model applications to the South Platte River in Colorado, and results, are discussed. Compared to other conjunctive use models, this does not require voluminous amounts of input data.

74:04B-003
MULTILEVEL OPTIMIZATION FOR CONJUNCTIVE USE OF GROUNDWATER AND SURFACE WATER,
Yu, W. and Haimes, Y.Y.
Case Western Reserve University, Cleveland, Ohio, Systems Research Center.
Water Resources Research, Vol. 10, No. 4, p 625-636, August 1974. 7 fig, 6 tab, 22 ref, 2 append.

Descriptors: *Conjunctive use, *Systems analysis, *Optimization, Groundwater resources, Surface waters, Water resources, Municipal water, Recharge, Imported water, Irrigation water, Industrial water.

A general systems analysis approach, not using straight simulation methods, was applied to the problem of optimal conjunctive use of groundwater, local surface water, and imported water resources. A water resources management problem was considered for a hypothetical region composed of several adjoining subregions overlying a common aquifer. The aquifer was represented by a two-dimensional asymmetrical grid network model. Local water agencies had exclusive rights for developing and controlling all water resources in its subregion. Water demands for each subregion were classified as agricultural or municipaleindustrial. A regional water authority optimally regulated the region's water resources by establishing intersubregional aquifer boundary conditions, and by imposing a pumping tax to pay the cost of recharging the aquifer. The solution was implemented by a completely decentralized decision making structure of two level hierarchy.

74:04B-004
ISOTOPIC AND CHEMICAL CHARACTERISTICS OF HIGH-LEVEL GROUNDWATER ON OAHU, HAWAII,
Hufen, T.H., Buddemeier, R.W. and Lau, L.S.
Hawaii University, Honolulu, Water Resources Research Center.
Water Resources Research, Vol. 10, No. 2, p 366-370, April 1974. 4 fig, 2 tab, 18 ref.

Descriptors: *Groundwater, *Geohydrology, *Radiocarbon, Tritium, Tunnels, Soil, Isotopes, Chemistry, *Hawaii, *Chemical properties.

High level dike-confined groundwaters and high-level perched groundwaters on Oahu, Hawaii, were analyzed for tritium, radiocarbon, carbon 13, and several chemical constituents. Discharges from several tunnels that tap dike compartments contain postbomb tritium, indicating the presence of modern (since 1954) recharge. The amount of this recharge in samples taken inside one of the tunnels is a function of the distance between overlying surface and sampling point. Chemical and carbon isotopic compositions of dike waters, established in the soil zone of their overlying ground surface, remain unchanged while the water is passing through the basaltic carbonate-free compartments. Dike water carbon isotope data are sufficiently consistent to serve as initial values for the dating of water in the Honolulu basal aquifers. The radiocarbon data suggest that the maximum value for residence of the dike waters is of the order of 100 years.

74:04B-005
THE OPERATION OF A STREAM-AQUIFER SYSTEM UNDER STOCHASTIC DEMANDS,
Maddock, T., III

Geological Survey, Reston, Virginia.
Water Resources Research, Vol. 10, No. 1, p 1-10, February 1974. 2 fig, 5 tab, 19 ref.

Descriptors: *Conjunctive use, *Stochastic processes, Statistical methods, *Water demand, Water yield, *Surface-groundwater relationships, Artificial recharge, Drawdown, Withdrawal.

It is possible to develop operating rules for the conjunctive use of surface water and groundwater when the demand and supply sources are stochastic. These rules allow the quantities of water pumped from wells, diverted from streams, spread, and returned to the stream after use to be determined for a given time period even if the required needs and availability of supply are uncertain at the beginning of the time period. These rules are dependent on a technological function relating streamflow interaction with well pumping and with the statistics of the demands, streamflow, pumping, and drawdowns. The discounted expected cost and the operating rules are functions of not only the expected value of the demands but also its variance and persistence (as measured by an autocorrelation function). The discounted expected cost has high sensitivity to demand variances and some sensitivity to persistence.

74:04B-006
GROUNDWATER MANAGEMENT AND SALINITY CONTROL,
Cummings, R.G. and McFarland, J.W.
Rhode Island University, Kingston, Department of Resource Economics.
Water Resources Research, Vol. 10, No. 5, p 909-915, October 1974. 37 ref.

Descriptors: *Groundwater resources, *Management, *Salinity, *Irrigation, *Water quality control, Analytical techniques, Methodology, Mathematical models, Water utilization, Taxes, Downstream, Equations, Economics, Agriculture, Water supply, Leaching, Soil moisture, Capital, Economic efficiency, Costs, Benefits, Systems analysis, Optimization.

Presented is an analytical framework for an integrated approach to the water-salinity management problem. The framework recognizes (1) the intertemporal problem of endogenously determined water scarcity and the ramifications of such scarcity for the opportunity cost of water used for leaching purposes, and (2) optimal investment rates for capital and the role of capital in reducing salinity as well as in 'saving' scarce water supplies. A mathematical model is presented that may be useful in analyzing decision rules for the conjunctive management of groundwater reserves for use in irrigation and salinity control. Policy implications of this approach are examined, particularly as they relate to the difficulties associated with the use of economic incentives for the purpose of bringing about optimal water use patterns in a decentralized decision-making government. Alternative schemes for decentralized management via taxes and bribes are discussed. Taxes are described that bring about intradistrict efficiency in terms of use and salinity control when downstream externalities are ignored. When externalities are considered, it is shown that a unique pattern of resource use requires a given institutional structure for the management of bribes.

74:04B-007
GROUND-WATER RECHARGE STRIP BASIN-EXPERIMENTS,
Brock, R.R. and Amar, A.C.
California State University, Fullerton, Department of Civil Engineering
Journal of the Hydraulics Division, American Society of Civil Engineers Vol 100, No. HY4, Paper 10503, p 569-592, April 1974. 12 fig, 2 tab, 15 ref, append

Descriptors: *Artificial recharge, *Groundwater recharge, *Hydraulic models, *Dupuit-Forchheimer theory, Porous media, Groundwater movement, Unsteady flow.

The problem of recharging a strip basin to a horizontal water table overlying an impervious base was formulated using the saturated flow equations. From this formulation the number of dimensionless variables that determine a dimensionless water table rise were identified using the exact or potential theory and an approximate (Dupuit-Forchheimer) theory. Experiments were performed in a 5-m long sand model. As a dimensionless recharge rate was increased, an expected systematic deviation from the theory is presumably a result of the invalidity of the assumption of the theory for deep flows. Experimental results are presented in the form of dimensionless graphs.

74:04B-008
SALINITY MANAGEMENT FOR HIGH FREQUENCY IRRIGATION,
Hoffman, G.J., Rawlins, S.L., Oster, J.D., and Merrill, S.D.
United States Department of Agriculture, Riverside, California.
Proceedings of the Second International Drip Irrigation Congress, pp. 372-375, July 1974. 4 fig.

Descriptors: *Salinity, *Saline soil, *Saline water, *Leaching, Grain sorghum, Lettuce, Wheat, Crop response, Irrigation practices, Irrigation, Agriculture.

A field plot experiment designed to determine the minimum leaching required to maintain crop yields under high frequency irrigation is described. Two varieties of wheat, grain sorghum, and lettuce are being grown in rotation each year in six replicated leaching fraction treatments. Precise measurements of the volume and salt concentration of the irrigation and drainage waters along with in-situ soil salinity measurements and crop yield are reported.

74:04B-009
IRRIGATION RETURN FLOW AS INFLUENCED BY DRIP IRRIGATION,
Patterson, T.C. and Wierenga, P.J.
New Mexico State University, Las Cruces, New Mexico.
Proceedings of the Second International Drip Irrigation Congress, pp. 376-381, July 1974. 2 fig, 3 tab, 4 ref.

Descriptors: *Return flow, *Water quality, *Salinity, *Surface irrigation, *Saline water, *Saline soil, New Mexico, Texas, Irrigation practices, Irrigation systems, Irrigation, Agriculture.

Deterioration of water quality in the Rio Grande is a major problem for water users in New Mexico and Texas. From near Santa Fe, New Mexico to El Paso, Texas, a distance of 270 miles, the total of dissolved solids increases from 221 ppm to 787 ppm while the percent of sodium increases from .25 near Santa Fe to 52 at El Paso. The deterioration in quality is due to the return of lower quality drainage water from the irrigated areas to the river. This paper describes a project designed to determine, under field conditions, rates of water and salt movement in the soil and subsequently to the drains as affected by frequency and amount of trickle irrigation, as compared to frequency and amount of surface water application. Both return flow quality and quantity are evaluated.

74:04B-010
SOIL SALINITY DISTRIBUTION IN SPRINKLER-AND SUBSURFACE-IRRIGATED CITRUS,
Nelson, S.D. and Davis, S.
Brigham Young University, Provo, Utah.
Transactions of the American Society of Agricultural Engineers, Vol. 17, No. 1, p 140-143, January-February 1974. 4 fig, 3 tab, 4 ref.

Descriptors: *Saline soil, *Salinity, *Sprinkler irrigation, *Subsurface irrigation, *Citrus fruits, Leaching, Irrigation practices, Irrigation effects, Irrigation systems, Irrigation, Agriculture.

Soil salinity distribution produced by subsurface irrigation results in maximum salt concentrations at the perimeter of the wetting front. The soil salinity increases most in the soil above the burial depth of the subsurface pipe. Winter rainfall could be effectively used to leach accumulated surface salts from the root zone of subsurface - irrigated citrus in southern California, by maintaining a high water content during the rainfall months, allowing precipitation to be used only for leaching and not for increasing the soil water content. By using this management method, a more favorable salt balance was maintained.

74:04B-011
FIELD LEACHING BY SPRINKLER AND SURFACE IRRIGATION DURING A CROP SEASON,
Hermsmeier, L.F. and Kaddah, M.T.
Imperial Valley Conservation Research Center, Brawley, California.
Transactions of the American Society of Agricultural Engineers, Vol. 17, No. 2, p 275-279, March-April 1974. 4 fig, 5 tab, 1 ref.

Descriptors: *Leaching, Sprinkler irrigation, Surface irrigation, Salinity, Irrigation practices, Irrigation effects, Irrigation operation and management, Irrigation water, Barley, Crop production, Irrigation, Agriculture.

Applying excess irrigation water to a winter barley crop can be used to leach salt from the soil at the same time crop production is proceeding. Surface irrigation and sprinkler irrigation were equally effective in leaching salt from the soil during a barley season. Application of more water between the drains than near the drains with sprinklers improved but slightly the salt removal between the drains in the top foot of soil and gave no greater improvement at a depth of 4 to 5 feet. Application of 30% excess water with surface irrigation and 67% excess water with sprinklers produces good barley yields.

74:04B-012
CRITICAL STATE OF SALT-WATER UPCONING BENEATH ARTESIAN DISCHARGE WELLS,
Streltsova, T.D. and Kashef, A-A.I.
Birmingham University, England, Department of Civil Engineering.
Water Resources Bulletin, Vol. 10, No. 5, p 995-1008, October, 1974. 4 fig, 1 tab, 10 ref.

Descriptors: Artesian aquifers, Artesian wells, Groundwater, Pumping, Saline water intrusion, Saline water-freshwater interfaces, Water resources, Free surfaced, Model studies.

An approach, based on the realization of the vertical components of flow is presented to determine the free surface of gravity wells and the shape of salt-water upcoming in artesian aquifers. The transitional stages from pumping fresh water to pumping salt water at the critical condition are discussed. Vertical hydraulic resistances, being determined and included in the flow domain, allow the use of the finite-difference approximation in a simple form. The suggested approach implies the use of either simple modeling or computing techniques.

74:04B-013
AN EVALUATION OF KINETIC AND EQUILIBRIUM EQUATIONS FOR THE PREDICTION OF PESTICIDE MOVEMENT THROUGH POROUS MEDIA,
van Genuchten, M. Th., Davidson, J.M., Wierenga, P.J.
New Mexico State University.
Soil Science Society of America Proceedings, Vol. 38, No. 1, p 29-35, January-February, 1974. 7 fig, 2 tab, 18 ref.

Descriptors: Herbicides, Adsorption, Simulation analysis, Model studies, Soil water movement, Pesticides, Pollutants.

Miscible displacement techniques were used to study the movement of picloram (4-amino-3,5, 6-trichloropicolinic acid) through a water-saturated Norge loam soil. The equilibrium adsorption and desorption isotherms for picloram and

Norge loam soil were not single-valued relations. Picloram movility was reduced significantly when the average pore-water velocity was decreased from 145 to 14.2 cm/day. Observed and predicted effluent concentration distributions were compared. Predictions were made with a S/360 CSMP simulation model, using two kinetic rate equations and an equilibrium Freundlich equation.

74:04B-014
UNSATURATED HYDRAULIC CONDUCTIVITY FROM CUMULATIVE INFLOW DATA,
Ahuja, L.R.
Hawaii University, Honolulu, Department of Agronomy and Soil Science.
Soil Science Society of America Proceedings, Vol. 38, No. 5, p 695-699,
September-October, 1974. 6 fig, 13 ref.
(See 74:02G-024)

74:04B-015
STEADY FLOWS OF WATER AND SALT IN UNIFORM SOIL PROFILES WITH PLANT ROOTS,
Raats, P.A.C.
U.S. Salinity Laboratory, Riverside, California.
Soil Science Society of America Proceedings, Vol. 38, No. 5, p 717-722,
September-October, 1974. 8 fig, 20 ref.
(See 74:02G-025)

74:04B-016
TWO-DIMENSIONAL DISPLACEMENT INTO OR FROM WATER-FILLED DITCHES,
Miyamoto, S. and Warrick, A.W.
Arizona University, Tucson, Department of Soils, Water and Engineering.
Soil Science Society of America Proceedings, Vol. 38, No. 5, p 723-726,
September-October, 1974. 5 fig, 1 tab, 11 ref, append.
(See 74:02G-026)

74:04B-017
CHLORIDE AND TRITIATED WATER FLOW IN DISTURBED AND UNDISTURBED SOIL CORES,
McMahon, M.A. and Thomas, G.W.
Kentucky University, Lexington, Department of Agronomy.
Soil Science Society of America Proceedings, Vol. 38, No. 5, p 727-732,
September-October, 1974. 6 fig, 4 tab, 13 ref.
(See 74:02G-027)

74:04B-018
ASSESSING SOIL SALINITY AND IDENTIFYING POTENTIAL SALINE-SEEP AREAS WITH FIELD SOIL RESISTANCE MEASUREMENTS,
Halvorson, A.D. and Rhoades, J.D.
United States Department of Agriculture, Agricultural Research Service, Sidney, Montana.
Soil Science Society of America Proceedings, Vol. 38, No. 4, p 576-581,
July-August, 1974. 7 fig, 4 tab, 12 ref.

Descriptors: *Soil salinity, *Salinity, *Soil tests, Soil properties, Electrical conductance.

The recent widespread increase in the occurrence of seep areas high in salinity in the northern Great Plains has increased the need for soil salinity research. The objective of the study was to examine the use of soil conductivity values calculated from resistance measurements obtained with the four-probe Wenner electrode configuration to identify potential saline-seep areas and estimate soil salinity in the field. Plots of apparent soil conductivity (EC) vs inner-electrode spacing (a) yielded different types of curves for saline-seep areas, recharge areas, and intermediate areas. Plots of Ec vs a or EC values alone can be used to identify potential saline-seep areas. Significant correlations were obtained in May (r=0.98) and August (r=0.96) between apparent soil conductivity (EC) and electrical conductivity of saturation extracts showing that four-probe soil resistance measurements can also be used to estimate soil salinity in the field.

74:04B-019
THE CONTROL OF NITRATE ACCUMULATION IN SOILS BY INDUCED DENITRIFICATION,
Avinimelech, Y. and Raveh, A.
Institute of Technology, Haifa, Israel.
The Journal of the International Association on Water Pollution Research,
Vol. 8, No. 8, p. 553-556, August, 1974. 2 fig, 1 tab, 8 ref.

Descriptors: *Nitrates, *Denitrification, Soil chemistry, Irrigation, Sprinkler irrigation, Irrigation effects, Soil profile.

Large amounts of nitrates are accumulating in the Hula Valley soils and then subsequently being leached to the Sea of Galilee. The nitrate concentration in the soil has been significantly reduced by induced denitrification. Reducing conditions have been achieved by controlled sprinkling of previously dried soil.

74:04B-020
MINIMIZING THE SALT BURDENS OF IRRIGATION DRAINAGE WATERS,
Rhoades, J.D., Oster, J.D., Ingvalson, R.D., Tucker, J.M., and Clark, M.
United States Department of Agriculture, Riverside, California, Agricultural Research Service, U.S. Salinity Laboratory, Western Region.
Journal of Environmental Quality, Vol. 3, No. 4, p 311-316, October-December, 1974. 7 tab, 7 ref.

Descriptors: *Salinity, *Saline water, *Drainage, *Drainage water, Lysimeter, Return flow, Water quality, Water pollution, Alfalfa, Saline soil, Irrigation, Irrigation practices.

The salt burdens of percolated drainage waters resulting from the use of waters, synthesized to represent eight important river waters of the western USA, for irrigation of alfalfa in a controlled lysimeter experiment, are presented. These data show that minimizing the quantity of drainage water resulted in the smallest possible return of applied salts in the return flow because: i) it maximizes the precipitation of carbonate minerals and gypsum in the soil, ii) it minimizes soil mineral weathering and the dissolution of salts previously deposited in the soil, and iii) it maximizes the amount of soluble salt diverted in the water that is retained in storage in the soil profile and not returned in the drainage water.

74:04B-021
GROUND WATER QUALITY RELATED TO IRRIGATION WITH IMPORTED SURFACE OR LOCAL GROUND WATER,
Nightingale, H.I. and Bianchi, W.C.
United States Department of Agriculture, Fresno, California, Agricultural Research Service, Water Management Research
Journal of Environmental Quality, Vol. 3, No. 4, p 356-361, October-December, 1974. 7 fig, 2 tab, 13 ref.

Descriptors: *Groundwater, *Water quality, Salinity, Saline water, Water pollution, Irrigation practices, Irrigation.

Ground-water quality in an arid irrigated area that imports high quality surface water was compared with an adjacent up-gradient area that uses local pumped ground water. A large irrigation canal separates the two areas which are up-gradient from the pumping depression of the Fresno-Clovis, California metropolitan area, which is dependent on ground water. Intensive sampling (154 wells) was done in the fall of 1972 after it was shown by previous sampling that the ground-water electrical conductivity (EC), NO(3), and Cl(-) content had not significantly changed since 1967. Diagrammatic distribution maps for ground water quality showed great variability. Areas of higher ground water NO(3) and Cl(-) were generally related to soil drainage-recharge and agricultural use. The use of local ground water without supplemental surface supplies above the canal has led to ground water EC, NO(3), and Cl(-) concentrations to be 9.5, 18.6, and 91.8% higher, respectively, than below the canal which uses mostly high quality surface water.

## WATER QUANTITY MANAGEMENT AND CONTROL

### WATERSHED PROTECTION (Group 04D)

74:04D-001
FIELD AND COMPUTER PROCEDURES FOR GULLY CONTROL BY CHECK DAMS,
Heede, B.H. and Mufich, J.G.
Forest Service (United States Department of Agriculture), Tempe, Arizona.
Forest Hydrology Laboratory.
Journal of Environmental Management, Vol. 2, p 1-49, 1974. 3 ref.

Descriptors: *Gully erosion, *Erosion control, *Check structures, *Sediment control, *Computer programs, *Construction costs, *Unit costs, *Benefits, Engineers estimates, Cost analysis, Surveys, Colorado, Rocky Mountain region, Arizona, New Mexico.

Computerized design of gully control by check dams eases field survey and design procedures. Only a minimum of data is required to generate the design of gully treatments and to yield essential information on costs and materials. Flexibility within the program is given by providing several design choices. Graphical computer output shows the relationships between the choices by effective dam height, total cost of treatment, and benefits from expected sediment deposits. Since key equations and their derivations are presented, the program can be adapted to dam types that differ from those used. The simplification of survey and design procedures makes feasible the inventorying of gully control needs for larger tracts of lands. The program is operational.

74:04D-002
DRIP IRRIGATION IN LANDSCAPING AND SOIL EROSION CONTROL,
Farrell, M.D.
Kuluwai Irrigation Corporation, Haleiwa, Hawaii.
Proceedings of the Second International Drip Irrigation Congress, pp. 44-45, July 1974.
(See 74:03F-024)

74:04D-003
NO-TILLAGE SYSTEM REDUCES EROSION FROM CONTINUOUS CORN WATERSHEDS,
Harrold, L.L. and Edwards, W.M.
United States Department of Agriculture, Agricultural Research Service, Coshocton, Ohio.
Transactions of the American Society of Agricultural Engineers, Vol. 17, No. 3,

Descriptors: *Soil erosion, *Corn, Crop response, Crop production, Farm management, Climatic data, Rainfall-runoff relationships, Agriculture, Erosion, Erosion control, Erosion rates.

Soil erosion from seven large events on the two watersheds in the same conventional rotation corn in the 1941-1969 period were sufficiently comparable to form a base on which to judge the effectiveness of the no-tillage system in the 1970-1973 period. Data for the period of identical treatment show little or no effect of land slope differences - 12.7% and 5.8%. In the period of continuous corn, 1970-1973, erosion from the conventional tillage corn watershed remained high, while that from the no-tillage corn system decreased sharply. In 1973, differences in soil erosion were striking. Photographs taken after the July 10, 1973 event show signs of large amounts of sediment movement from the conventional tillage corn watershed. There was no evidence of sediment movement from the continuous corn watershed in the no-tillage system.

**74:04D-004**
**WATERSHED MANAGEMENT WITHOUT SURFACE RUNOFF,**
**Manbeck, D.C.**
**Nebraska University, Lincoln, Department of Agricultural Engineering.**
**Water Resources Bulletin, Vol. 10, No. 3, p 586-591, June, 1974. 2 fig.**

**Descriptors: *Watershed management, *Surface runoff, Alternative planning, Constraints, Design, Retention.**

**Legal, economic, and social constraints prevented the development of a surface outlet from an 878 acre watershed in the eastern Great Plains. However, frequent flooding of potentially excellent cropland within the watershed had to be controlled. The process of considering various alternatives within given constraints and utilizing natural features of the watershed to attain a water management system without surface runoff is presented. The coordinated system includes surface drainage, waterholding structures, and pumping plants. The excellent water control provided permits effective utilization of more than 115 acres of land which was previously of very low productivity.**

74:04D-005
EVALUATION OF PHOSPHORUS DYNAMICS IN A WATERSHED,
Cahill, T.H., Imperato, P. and Verhoff, F.H.
Tri-County Conservancy of the Brandywine, Chaddas Ford, Pennsylvania.
Journal of the Environmental Engineering Division, Vol. 100, No. EE2, p 439-458, April, 1974. 7 fig, 6 tab, 29 ref, 2 append.

Descriptors: *Phosphorus, Watershed management, Dynamics, River flow, Rivers, Pollutants, Scour, Runoff

Investigations into the phosphate dynamics of the Brandywine River during the summer of 1972 indicates that phosphate transport occurs by two different mechnisms depending upon the type flow found in the river. If the flow is steady, the Brandywine phosphate concentrations as a function of flow exhibit what has been termed the dilution effect. This effect is definitely shown to result from the dilution of point source orthophosphate by the lower orthophosphate concentration water coming from nonpoint sources. During unsteady stage flow, the phosphate concentrations tends to increase with increasing water flow rate. Two possible explanations appear plausible: the phosphate concentration is increased by the scouring of the sediments which are high in adsorbed phosphate, or the phosphate concentration is increased from the runoff from limited areas near the waterway. In contrast to the steady state phosphate concentration data, the unsteady stage data shows no significant effect of point sources of phosphates.

# Section XVI

## WATER QUALITY MANAGEMENT AND PROTECTION

### IDENTIFICATION OF POLLUTANTS (Group 05A)

74:05A-001
QUANTITATIVE METHODS FOR PRELIMINARY DESIGN OF WATER QUALITY SURVEILLANCE SYTEMS,
Chamberlain, S.G., Beckers, C.V. Grimsrud, G.P. and Shull, R.D.
Raytheon Company, Portsmouth, Rhode Island, Oceanographic and Environmental Services.
Water Resources Bulletin, Vol. 10, No. 2, p 199-219, April 1974. 8 fig, 2 tab, 17 ref.

Descriptors: *Monitoring, *Water quality, *Water pollution control, Network design, Sampling, Cost-benefit analysis, Mathematical models, Data processing, *Indiana, *Illinois.

A preliminary phase of the design of water quality surveillance systems is the specification of sampling frequencies and station locations throughout the basin; that is, the development of an adequate space/time sampling plan. Quantitative methods were developed to identify candidate sets of sampling frequencies and station locations, and to establish priorities for implementing the different frequencies and locations. These methods are useful in cost/effectiveness analyses, and are based on the objective of pollution abatement. A spatial priority measure is dependent both on the water quality profile in the stream and on the information obtained from monitoring stations in other streams. A temporal sampling priority rating is a measure of the effectiveness of the surveillance system with respect to its ability to detect the violations in the standards. To illustrate the quantitative methods, the procedures were applied to the Wabash River Basin.

74:05A-002
DETERMINATION OF TRACE METALS IN SODIUM DITHIONITE-CITRATE EXTRACTS OF SOILS AND SEDIMENTS BY ATOMIC ABSORPTION,
Jenne, E.A., Ball, J.W. and Simpson, C.
Geological Survey, Menlo Park, California, Water Resources Division.
Journal of Environmental Quality, Vol. 3, No. 3, p 281-287, July-September 1974. 2 fig, 4 tab, 32 ref.

Descriptors: *Trace elements, *Soils, *Sediments, *Chemical analysis, *Flame photometry, Solvent extractions, Analytical techniques, Cobalt, Copper, Nickel, Molybdenum, Zinc, Iron, Trace elements, *Pollutant identification.

A general method was developed for the analysis of Co, Cu, Ni, Mo, and Zn in dithionite-citrate extracts of soils and sediments. Because of the high Zn content of dithionite, it is necessary to preclean the dithionite-citrate solution before it is used to extract soils or sediments. This precleaning lowers the detection level significantly for other trace elements as well. Since Fe causes flame interferences in atomic absorption, the size of the individual sample aliquot taken to chelation-solvent concentration is varied to provide a constant quantity of Fe (5ng). The standards and blanks are adjusted to the same Fe content. This approach is necessitated by the wide differences in the Fe concentrations of the dithionite-citrate extracts. Following pH adjustments and addition of ammonium-1-pyrrolidine dithiocarbamate, the trace metals (and Fe) are concentrated via two successive 10ml methyl isobutyl ketone extractions. Quantities of Fe much greater than 5ng interfere

**in the solvent concentration step. Natural organics released by the dissolution of free-Fe and -Mn oxides, to the extent that they are represented by fulvic acids, do not cause any significant interference.**

74:05A-003
THE UNRELIABILITY OF TILE EFFLUENT FOR MONITORING SUBSURFACE NITRATE-NITROGEN LOSSES FROM SOILS,
Thomas, G.W. and Barfield, B.J.
Journal of Environmental Quality, Vol. 3, No. 2, p 183-185, April-June, 1974.
1 fig, 2 tab, 5 ref.

Descriptors: *Nitrate, *Nitrogen, *Denitrification, Drainage, Tile drainage, Soil water movement, Soil investigations, Seepage

Investigation of a completely tiled field showed that only a small proportion of the total flow reaching the drainage ditch came from tile effluent. In two measurements, 63 and 89% of the flow to the drainage ditch came from seepage other than through tiles. The nitrate-nitrogen concentrations in the tile effluent were far higher than those calculated in the non tile flow by mass balance. We conclude that nitrate-nitrogen concentrations in tile effluents may not be reliable indicators of nitrate-nitrogen losses from agricultural land, when the tiles do not intercept all subsurface flow.

# Section XVII

## WATER QUALITY MANAGEMENT AND PROTECTION

### SOURCES OF POLLUTION (Group 05B)

74:05B-001
NONLINEAR PROGRAMMING IN RIVER BASIN MODELING,
Bayer, M.B.
Calgary University, Alberta, Faculty of Business.
Water Resources Bulletin, Vol. 10, No. 2, p 311-317, April 1974. 3 tab, 31 ref.

Descriptors: *Water quality control, *Model studies, *River basins, Linear programming, *Dynamic programming, Costs, Optimization, Treatment facilities, Biochemical oxygen demand, Dissolved oxygen, Standards, Streams, Systems analysis, *Oregon.

Since the real world is seldom linear, nonlinear programming is theoretically the ideal method for obtaining solutions for complex water quality problems. The use of nonlinear programming in river basin water quality modeling is explored. Applications recently reported in the literature, along with the author's experience with nonlinear programming, are reviewed. Several difficulties which still exist in applying the method are discussed. Computational results obtained using linear, dynamic, and nonlinear programming to solve a river basin water quality optimization problem are compared. Data are from Liebman's simplified version of the Willamette River system in Oregon. The water quality models have objective functions with continuous first partial derivatives, and several inequality and variable bound constraints. Results obtained are the efficiencies of treatment plants and the total cost of building or expanding the treatment plants to accommodate specified BOD loads and stream DO standards. Compared are a linear and nonlinear program of Bayer, a dynamic program of Liebman, and a linear program of ReVelle.

74:05B-002
ADSORPTION OF PHOSPHATE BY RIVER PARTICULATE MATTER,
Wang, W-C.
Illinois State Water Survey, Peoria. Water Quality Section.
Water Resources Bulletin, American Water Resources Association, Vol. 10, No. 4, p 662-671, August 1974. 6 fig, 1 tab, 13 ref.

Descriptors: *Adsorption, *Sediments, *Phosphates, Water pollution sources, Isotherms, Montmorillonite, Bentonite, Laboratory tests, Suspended solids, Illinois.

Adsorption of orthophosphate on samples of particulate matter taken from the Illinois and Spoon Rivers was investigated under laboratory conditions. Adsorption equilibria were reached in four to six days. Average adsorption rates between 0.0239 and 0.0366 were found during equilibration periods. Adsorption isotherms were computed, both for constant and for varying amounts of particulate matter in the two rivers. During investigation of the effects of pH on phosphate adsorption, the highest adsorptive capacities were found at natural pH values of 8.3-8.4. Reductions in pH dropped this capacity to a minimum at pH6. Some slight recovery of capacity was observed at pH5 and 4. Rates of adsorption were influenced by the equilibrium concentration of phosphate-P and were essentially the same for the Illinois and Spoon Rivers. However, based upon the quantity of phosphate-P adsorbed per unit weight of particulate matter present, the capacity of the Illinois was seven times that of the Spoon River. Adsorption isotherms for both streams were essentially linear, suggesting a functional relation between unit adsorption and particulate matter content. A concurrent study of samples collected daily from the Illinois River failed to show a similar correlation of particulate matter and phosphate adsorption.

74:05B-003
NUMERICAL AND ANALYTICAL SOLUTIONS OF DISPERSION IN A FINITE, ADSORBING POROUS MEDIUM,
Marino, M.A.
California University, Davis, Department of Water Science and Engineering.
Water Resources Bulletin, Vol. 10, No. 1, p 81-90, February 1974. 1 fig, 6 ref.

Descriptors: *Dispersion, *Path of pollutants, *Porous media, *Numerical analysis, Mathematical models, Groundwater movement, Adsorption.

Numerical and analytical solutions are developed for the distribution of a contaminant within an adsorbing porous medium in a unidirectional flow field subject to a step function for input concentration. The medium is considered to be homogeneous, isotropic, and areally finite. As a byproduct, solutions are also obtained for the case of a nonabsorbing porous medium. An example that demonstrates the applicability of the solutions is presented.

74:05B-004
EFFECT OF TWO IMPOUNDMENTS ON THE SALINITY AND QUANTITY OF STORED WATERS,
Pionke, H.B. and Workman, O.D.
Agricultural Research Service, Chickasha, Oklahoma, Southern Great Plains Watershed Research Center.
Water Resources Bulletin, Vol. 10, No. 1, p 66-80, February 1974. 6 fig, 2 tab, 7 ref.

Descriptors: *Salinity, *Evaporation, *Reservoirs, *Oklahoma, Water quality, Water pollution sources, Seepage, Saline water, Flood control, Water chemistry, Impoundments.

The effect of hydrologic and chemical processes on salinization of stored waters was determined for two small floodwater-retarding structures located in western Oklahoma. One structure, designed to accommodate a large influx of sediment, was overdesigned (operated at reduced capacity) by upstream diversion of approximately one-half the inflow. Over a 2-year period, the total salinity of stored waters increased approximately 22 times, and the stored water volume decreased to 1/33 its initial volume in the overdesigned (underused) structure, while both volume and salinity of stored waters remained comparatively stable in the other structure. The lack of sufficient dilution by better quality surface runoff and the increased residence time of water in the impoundment apparently caused most of the salinity increase. The bulk of the salt load entering the overdesigned structure, to be concentrated later by evaporation, was associated with base rather than storm inflow. After base inflow ceased, substantial losses of salt load and stored water occurred concurrently. The loss was not adequately explained by chemical precipitation in association with evaporation. Seepage and evaporation appeared to account for much of the hydrologically unexplained loss of stored waters.

74:05B-005
WATER QUALITY SIMULATION AND APPLICATION,
Lombardo, P.S. and Ott, R.F.
Environmental Research and Technology, Incorporated, Lexington, Massachusetts.

Water Resources Bulletin, Vol. 10, No. 1, p 1-9, February 1974. 5 fig, 10 ref.

Descriptors: Water resources development, *Management, *Long-range planning, *Water quality, *Simulation analysis, *Optimum development plans, River basins, Water utilization, *Washington, Biochemical oxygen demand, Dissolved solids, Climatic data, Hydrologic data, Mathematical models, Systems analysis, Evaluation, Equations.

An understanding of the causes of aquatic system behavior leading to proper system management is enhanced by knowledge obtained through water quality modeling. For accurate assessment of the quality of a water body, the dynamic and synergistic character of the aquatic environment necessitates knowing the temporal and spatial varying behavior of various water quality indices. Through mathematical formulations of the physical, biological and chemical processes occurring in the aquatic ecosystem, water quality models attempt to simulate the spatial and temporal variations in water quality indices. Described in detail is the Hydrocomp Water Quality Simulation Model and its application to the Seattle metropolitan area. Model input includes rate of coliform die-away and BOD decay and climatological and hydrologic data; determination of total dissolved solids is done predominantly by a mass balance equation. The Seattle study searches for a plan to ensure the best utilization of the total water resources available to the Cedar and Green River basins, and includes evaluation of interbasin transfer. The Model provides a means for evaluating management policies in terms of the water quality indices. Through information generated on the probable resulting effects of policies, optimization of the various alternatives could be achieved.

74:05B-006
PREDICTING PESTICIDE RUNOFF FROM AGRICULTURAL LAND: A CONCEPTUAL MODEL,
Bailey, G.W., Swank, R.R., Jr., and Nicholson, H.P.
Environmental Protection Agency, Athens, Georgia, Agro-Environmental Systems Branch.
Journal of Environmental Quality, Vol. 3, No. 2, p 95-102, April-June 1974.
4 fig, 47 ref.

Descriptors: *Path of pollutants, *Pesticides, *Runoff, *Mathematical models, Model studies, Rainfall-runoff relationships, Translocation, Erosion, Pesticide kinetics.

A mathematical model of the dynamic, single-rainfall-event type describes pesticide runoff as a function of pesticide and soil properties, agricultural practices, watershed characteristics, and climatic factors. The conceptual structure of the model includes source term effects, loss of pesticide from the soil surface during runoff producing rainfall events because of mass transfer from soil surface into the moving runoff film and pickup of sediment containing pesticide particulates.

74:05B-007
RELATIVE MOVEMENT OF BROMIDE AND NITRATE THROUGH SOILS,
Smith, S.J. and Davis, R.J.
Agricultural Research Service, Durant, Oklahoma, Water Quality Management Laboratory.
Journal of Environmental Quality, Vol. 3, No. 2, p 152-155, April-June 1974.
3 fig, 4 tab, 14 ref.

Descriptors: *Leaching, *Path of pollutants, *Nitrates, *Bromides, Biodegradation, Nutrients, Anion exchange, Soils.

Miscible displacement experiments were conducted with eight different surface soils (0-15 cm depth) and their associated subsoils (61-76 cm depth). Results indicate that the movement of bromide relative to that of nitrate is identical in subsoils but variable in surface soils. Differences in relative movement of the two anions may be attributed to microbial activity involving nitrate. With the exception of 5% anion sorption in a Greenville subsoil, anion exclusion values ranged from 5% to 39%, indicating the anions were moving 1.05 to 1.64 times as fast as they would if they had been uniformly associated with all the soil water. The results support the view that bromide has utility for following the potential path of nitrate movement through soils.

74:05B-008
EROSIONAL LOSSES OF S-TRIAZINE HERBICIDES,
Hall, J.K.
Pennsylvania State University, University Park, Department of Soil Chemistry.
Journal of Environmental Quality, Vol. 3, No. 2, p 174-180, April-June 1974.
4 fig, 2 tab, 15 ref.

Descriptors: *Soil erosion, *Runoff, *Herbicides, *Path of pollutants, *Pesticide residues, Pesticides, Alfalfa, Corn(Field).

Erosional losses of two chloro-s-triazines, atrazine and GS13529, were evaluated in 1970 and 1971 from field runoff plots planted to corn and situated on Hagerstown silty clay loam of 14% slope. Losses of a methoxy-s-triazine, GS14254, were assayed in 1971 and 1972 from an alfalfa stand. Herbicides were applied premergent to corn and to dormant alfalfa only once during the initial growing season or initial season of evaluation of two rates, 2.2 and 4.5 kg/ha. Total losses of atrazine during the first and most critical season at the respective rates were 5.0% and 4.8% of that applied; 87% to 93% of this loss resulted within the first month following application. One month after application an average of 35.3% of the applied atrazine remained; five months later an average level of 11.8% was residual. Recovery of GS13529 ranged from 65.5% to 9.8% for the same time period. Runoff losses of GS14254 from alfalfa were inconsequential. Little runoff was obtained from this cropping system, no sediment was ever collected and runoff concentrations of the herbicide were extremely small. Total losses of this herbicide for the year were 0.02 and 0.03% for the respective application rates.

74:05B-009
NITRATE-NITROGEN AND PHOSPHORUS CONTENTS OF STREAMS DRAINING SMALL AGRICULTURAL WATERSHEDS IN KENTUCKY,
Thomas, G.W. and Crutchfield, J.D.
Kentucky University, Lexington, Department of Agronomy.
Journal of Environmental Quality, Vol. 3, No. 1, p 46-49, January-March 1974.
5 fig, 2 tab, 3 ref.

Descriptors: *Nitrates, *Phosphorus, *Small watersheds, *Kentucky, *Land use, Fertilizers, Hydrogeology, Water pollution sources.

Eight streams draining agricultural watersheds representative of the important physiographic regions of Kentucky were sampled monthly from January through May in both 1971 and 1972. The objective was to determine the effects of land use and geology on the concentrations of nitrate-N and P in the stream water. The land use ranged from almost completely forested to mostly cultivated. There was no good relationship between nitrate-N and land use. Nitrate-N varied from 6 ppm to zero, with the highest value found in a stream draining a watershed which was 98% in bluegrass pasture. The P concentrations in the stream water were closely related to local geology and not to land use. A comparison between the 1921 data and 1971-72 data from the same geological areas showed very little change in mean nitrate-N or P concentrations.

74:05B-010

SURFACE RUNOFF LOSSES OF SOLUBLE NITROGEN AND PHOSPHORUS UNDER TWO SYSTEMS OF SOIL MANAGEMENT,

Klausner, S.D., Zwerman, P.J. and Ellis, D.F.

Cornell University, Ithaca, New York, Department of Agronomy.

Journal of Environmental Quality, Vol. 3, No. 1, p 42-46, January-March 1974.
4 fig, 4 tab, 15 ref.

Descriptors: *Agricultural runoff, *Nitrogen, *Phosphorus, *Soil management, Nutrients, Agriculture, Rainfall-runoff relationships, Crops, Fertilization, Eutrophication, Rotation, *New York.

Annual loss of soluble nitrogen and inorganic phosphorus from field plots, due to rainfall, was determined. Influence of a crop rotation, soil management practices and fertilizer rates was evaluated. The experimental area is composed of approximately 12 ha of a Lima-Kendaia soil association. The soil texture is silt loam and is moderately to somewhat poorly drained. A three-year crop rotation of corn, beans, and wheat were combined factorially with two levels of fertility and two soil management schemes and replicated twice. The crop rotation has persisted for 15 years and has gone through five cycles. The soil management variable had remained the same for each plot during this period. The data present the annual losses of soluble N and P in the liquid fraction of surface runoff, as a function of past soil management practices and present fertility levels. Mean annual surface runoff volumes were approximately twice as high from poorly managed soils than from well-managed soils. Except for heavy fall fertilization of N on poorly managed soils, total yearly accumulative N discharge in surface runoff did not exceed amount delivered in rainfall as measured over 10 months. Phosphorus losses exceeded the amount contained in rainfall.

74:05B-011

PHOSPHORUS RELATIONSHIPS IN RUNOFF FROM FERTILIZED SOILS,

Romkens, M.J.M. and Nelson, D.W.

Agricultural Research Service, Lafayette, Indiana.

Journal of Environmental Quality, Vol. 3, No. 1, p 10-13, January-March 1974.
4 fig, 2 tab, 14 ref.

Descriptors: *Water pollution sources, *Phosphorus, *Fertilizers, *Phosphates, *Soil water movement, Erosion, Sediments, Path of pollutants.

The effect of fertilizer mixed into soil on the amount of phosphorus in runoff was studied. Runoff samples from artificial rainstorms on fallow plots of Russell sil soil, and P enriched soil-water mixtures (1:50) of Russell sil and other soils were analyzed for water soluble orthophosphate and extractable, total, and organic P in sediment. The relation of P addition rate to the soluble orthophosphate or sediment extractable phosphorus level in runoff was approximately linear. The relation of soluble orthophosphate to extractable P in soil-water systems was linear for most soils studied. Soluble orthophosphate and extractable P in sediment were not related to total P or to organic P in sediment. A procedure is suggested for estimating the soluble orthophosphate concentration in runoff from fertilized wet soil using laboratory analyses.

74:05B-012

NUTRIENTS IN SUBSURFACE AND RUNOFF WATERS OF THE HOLLAND MARSH, ONTARIO,
Nicholls, K.H. and MacCrimmon, H.R.
Ministry of the Environment, Rexdale, Ontario, Water Quality Branch.
Journal of Environmental Quality, Vol. 3, No. 1, p 31-35, January-March 1974.
3 fig, 2 tab, 18 ref.

Descriptors: *Nutrients, *Path of pollutants, Water pollution sources, *Marshes, Soils, *Canada, *Fertilizers, *Nitrogen, *Phosphorus, Nitrates, Nitrites, Runoff.

Relative contributions to the river of nutrients (NO3, NO2, and total and soluble reactive phosphorus) and total electrolyte (specific conductance) were determined in surface runoff water pumped from both cultivated and uncultivated plots of much soil within the Holland Marsh, Ontario. In addition, subsurface water from piezometers installed in both cultivated and uncultivated marsh soil was analyzed throughout the growing season to determine fundamental differences in water chemistry and the extent of leaching of N and P under both cultivated and uncultivated conditions. The time and amount of rainfall are important in determining nitrate-N and to a lesser extent, soluble reactive P concentrations in subsurface water beneath the cultivated plot but not beneath the uncultivated plot. The mean concentration (0.75 mg/liter) of inorganic N in subsurface water under the cultivated plot was about 10 times higher than under uncultivated marsh during the growing season. The combined effects of fertilization, drainage and hence oxidizing and nitrifying conditions yielded 4 to 5 times more P (1.56 kg P/ha) and 40 to 50 times more nitrate-N (4.1 kg N/ha) in runoff water from the cultivated than from the uncultivated plot. From the cultivated plot the nutrients are lost to the river during a 5 to 6 week pumping period during the spring and more than 90% of the total P in runoff is in the soluble reactive form (as opposed to only 45% from the uncultivated marsh) and is, therefore, readily available for algae and aquatic plant growth in the lower Holland River and Cook Bay of Lake Simcoe.

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74:05B-013

MODELING FLOW AND CHEMICAL QUALITY CHANGES IN AN IRRIGATED STREAM-AQUIFER SYSTEM,
Konikow, L.F. and Bredehoeft, J.D.
Geological Survey, Lakewood, Colorado.
Water Resources Research, Vol. 10, No. 3, p 546-562, June 1974. 25 fig, 3 tab, 30 ref.

Descriptors: *Water quality, *Groundwater movement, *Path of pollutants, *Return flow, *Numerical analysis, Surface-groundwater relationships, Unsteady flow, Mathematical models, Alluvial channels, Dissolved solids, Conjunctive use, *Colorado.

Salinity increases in groundwater and surface water in the Arkansas River valley of southeastern Colorado are primarily related to irrigation practices. A digital computer model was developed to predict changes in dissolved solid concentration in response to spatially and temporally varying hydrologic stresses. The equations that describe the transient flow of groundwater and the transport and dispersion of dissolved chemical constituents were solved numerically. The model simulated flow as well as changes in water quality for both the stream and the aquifer. Detailed field measurements made for a 1-yr period in an 11-mi reach of the valley between LaJunta and the Bent-Otero country line were used to verify and calibrate the model. Measured water levels varied by an average of about 3 ft during the study period, and calculated water table elevations in the aquifer were within 1 ft of the observed values approximately 90% of the time. The specific conductances of water samples from five wells in one well field had a standard deviation of about 10% of the mean. Dissolved solid concentrations calculated by the model were within 10% of the observed values for both the aquifer and the stream approximately 80% of the time.

74:05B-014

QUALITY OF WATER DISCHARGED FROM TWO AGRICULTURAL WATERSHEDS IN SOUTHWESTERN IOWA,

Burwell, R.E., Schuman, G.E., Piest, R.F., Spomer, R.G. and McCalla, T.M.

Agricultural Research Service, Council Bluffs, Iowa, North Central Watershed Research Center.

Water Resources Research, Vol. 10, No. 2, p 359-365, April 1974. 5 tab, 15 ref.

Descriptors: *Water quality, *Sediment yield, *Soil conservation, Land management, *Iowa, Pesticides, Contour farming, Terracing, Farm management.

To evaluate the influence of the level-terrace conservation practice on water, sediment, and plant nutrients discharged in surface runoff and base flow, data obtained from this watershed were compared with data obtained from a 33.6-ha contour-planted corn-cropped watershed near Treynor, Iowa. The quality of water discharged from the 157.5-ha diversified conservation-farmed watershed in southwestern Iowa was within acceptable limits for potable water except for the levels of ammonia, inorganic phosphorus, and coliform. Total coliform levels exceeded the established criteria on two occasions, and fecal coliform once during the 2-year study. Nutrient concentration was high occasionally, but the nutrient quantities discharged from the watershed were low, showing the effectiveness of the level-terrace system in controlling surface runoff and erosion. Atrazine residue in the runoff and sediment was detected in only one sample. Even though several chlorinated hydrocarbon and organophosphate compounds had been applied to the watershed, none was detected in runoff or sediment. A comparison of the data from the 33.6-ha contour-farmed watershed with the data from the 157.5-ha well-planned conservation watershed showed the benefits and necessity of controlling runoff and erosion to prevent loss of agricultural chemicals.

74:05B-015

SOLUBLE PHOSPHATE OUTPUT OF AN AGRICULTURAL WATERSHED IN PENNSYLVANIA,

Gburek, W.J. and Heald, W.R.

Agricultural Research Service, University Park, Pennsylvania, Northeast Watershed Research Center.

Water Resources Research, Vol. 10, No. 1, p 113-118, February 1974. 1 fig, 1 tab, 10 ref.

Descriptors: *Phosphates, *Water pollution sources, *Fertilizers, Leaching, Land use, *Pennsylvania, Path of pollutants, *Agricultural watersheds.

Soluble phosphate data were collected from the stream draining a 7.7 sq km Pennsylvania agricultural watershed. The stream approaches constant and low phosphate concentrations of 10 ppb or less PO4-P during continuing base flow recession. Concentrations vary seasonally, 10 to 15 ppb PO4-P commonly occurring in the summer. Less than 2% of the P applied to the watershed as fertilizer is carried out of the watershed by the stream in the soluble form. Most of this output is associated with the high flows and low concentrations found in the early spring. The land adjacent to the stream channel and its indigenous vegetation can be a direct source of soluble phosphate to the stream during periods of precipitation. This makes the PO4-P levels observed at the watershed outlet the result of near- and in-stream processes and reduces the importance of general land use of a watershed as a determining factor in the soluble phosphate concentrations in the stream.

74:05B-016
WATER QUALITY MODELS USING THE BOX-JENKINS METHOD,
Huck, P.M. and Garquhar, G.J.
Environmental Protection Service, Burlington, Ontario, Waste Water Technology Centre.
Journal of the Environmental Engineering Division, American Society of Civil Engineers, Vol. 100, No. EE3, Paper 10629, p 733-752, June 1974. 9 fig, 7 tab, 13 ref, append.

Descriptors: *Time series analysis, *Path of pollutants, Water quality, *Statistical models, Water pollution, Chlorides, Dissolved oxygen, Model studies, Time series analysis.

The Box-Jenkins method, a time-based technique for time series analysis, is successful in modeling chloride and dissolved oxygen data for the St. Clair River near Corunna, Ontario. The technique is superior in the situation to either a frequency-based approach or a deterministic causative model. The model building process includes identification, estimation, and diagnostic checking stage. Forecasting and interpretation follow the derivation of successful models. An autoregressive type of model best represents the chloride data, and a moving average process represents the dissolved oxygen. Similar causative mechanisms appear to influence June and December chloride and June dissolved oxygen.

74:05B-017
A KINETIC STUDY OF AMMONIUM AND NITRITE OXIDATION IN A SOIL FIELD PLOT,
Ardakani, M.S., Schulz, R.K. and McLaren, A.D.
California University, Berkeley, Department of Soils and Plant Nutrition.
Soil Science Society of America Proceedings, Vol. 38, No. 2, p 273-277, March-April 1974. 6 fig, 1 tab, 13 ref.

Descriptors: *Oxidation, *Ammonia, *Nitrates, Soils, Nitrification, Denitrification, Soil microorganisms, Adsorption, Biodegradation.

Disappearnace of NH4 from percolating solution in a field test was attributed to both oxidation and to adsorption by the soil. Once a steady state was established and exchangeable NH4 was equilibrated with NH4 in soil solution, oxidation alone accounted for disappearance of NH4 in the top 2.5 cm of the soil. Concentration profiles of NO2 and NO3 may be described by a modified Michaelis-Menten equation. Rate constants for oxidation of NO2 and NH4 are 0.0006 and 0.0025, respectively. These rates are in good agreement with the values found under controlled laboratory conditions. Growth and distribution in soil of Nitrobacter and Nitrosomonas were followed by weekly estimates of their numbers at different depths. Nitrobacter reached a maximum population of about 1 million per cc of soil but declined to a stable density of about 100,000 organisms per cc. Nitrobacter approached a steady level of about 10,000 organisms per cc. Both organisms showed higher densities near the soil surface where the concentrations of substrates were always highest.

74:05B-018
NITROGEN TRANSFORMATIONS DURING CONTINUOUS LEACHING,
Starr, J.L., Broadbent, F.E. and Nielsen, D.R.
California University, Davis, Department of Soils and Plant Nutrition.
Soil Science Society of America Proceedings, Vol. 38, No. 2, p 283-289, March-

April 1974. 9 fig, 17 ref.

Descriptors: *Nitrification, *Denitrification, *Leaching, *Unsaturated flow, Ammonia, Oxidation, Soil water movement, Diffusion, Path of pollutants, Equations, Reduction(Chemical).

Simultaneous nitrification, denitrification, and N movement were investigated in a soil column during continuous unsaturated leaching. During a continuous application of NH4Cl solution, analyses were made of the soil solution with soil depth and time for N as NH4, NO2 and NO3; and of the soil atmosphere for O2, CO2, N2O, and N2. The use of N-15 permitted direct measurement and quantification of nitrification and denitrification, as well as the transport of N in the liquid and gaseous phases. Solutions to the appropriate equations using measured reaction rate coefficients, pore-water velocities, and diffusion coefficients adequately described the steady state NH4 and NO3 concentration distribution in the soil profile. Equations were also used to stoichiometrically account for the various interacting species in the N transformations.

74:05B-019
NITROGEN TRANSFORMATIONS IN SOIL DURING LEACHING: I. THEORETICAL CONSIDERATIONS,
Misra, C., Nielsen, D.R. and Biggar, J.W.
California University, Davis, Department of Water Science and Engineering.
Soil Science Society of America Proceedings, Vol. 38, No. 2, p 289-293, March-April 1974. 12 ref.

Descriptors: *Nitrification, *Denitrification, *Leaching, *Unsaturated flow, Ammonia, Oxidation, Soil water movement, Diffusion, Path of pollutants, Equations, Reduction(Chemical).

Transport equations describing the movement and simultaneous oxidation of NH4 to NO3 and reduction of NO3 and N2 by microbial and chemical means were set up and solved both for leaching of a pulse and for a continuous application at the soil surface. Both ionic adsorption owing to cation exchange and microbiological transormations were considered and distinguished as reversible and irreversible processes, respectively. The possibilities of the model extended to a sequential transformation during transport of more than two nitrogen species have been examined.

74:05B-020
NITROGEN TRANSORMATION IN SOIL DURING LEACHING: II. STEADY STATE NITRIFICATION AND NITRATE REDUCTION,
Misra, C., Nielsen, D.R. and Biggar, J.W.
California University, Davis, Department of Water Science and Engineering.
Soil Science Society of America Proceedings, Vol. 38, No. 2, p 294-299, March-April 1974. 5 fig, 1 tab, 19 ref.

Descriptors: *Nitrification, *Denitrificaion, *Leaching, *Unsaturated flow, Ammonia, Oxidation, Soil water movement, Diffusion, Path of pollutants, Equations, Reduction(Chemical).

Nitrogen transformations were examined by means of a miscible displacement technique that permitted passage of air with different levels of oxygen through the soil. With the use of steady-state solutions of equations describing the convective transport of NH4 and NO3 ions in Columbia silt loam, first-order reaction rate constants k1 and k2 were ascertained for NH4-oxidation and NO3-reduction, respectively. Values of k1 were 10-fold greater than those of k2. At an oxygen level of 0.5% in the gaseous phase, nitrification was apparently inhibited.

74:05B-021
NITROGEN TRANSFORMATIONS IN SOIL DURING LEACHING: III. NITRATE REDUCTION IN SOIL COLUMNS,
Misra, C., Nielsen, D.R. and Biggar, J.W.
California University, Davis, Department of Water Science and Engineering.
Soil Science Society of America Proceedings, Vol. 38, No. 2, p 300-304, March-April 1974. 7 fig, 1 tab, 11 ref.

Descriptors: *Nitrification, *Denitrification, *Leaching, *Unsaturated flow, Ammonia, Oxidation, Soil water movement, Diffusion, Path of pollutants, Equations, Reduction(Chemical).

Nitrate reduction in water-unsaturated Columbia silt loam columns was examined at 19.5C and 34.5C with three levels of oxygen (0.5%, 5%, and 20%) in an aerating gas passing through the soil. Following a continuous application of NH4 solution, a pulse of a NO3 solution was leached through the columns. After the decay of the pulse, a continuous application of NO3 solution allowed mathematical analysis leading to ascertaining NO3 reduction rate coefficients. The temperature dependence of these constants as a function of oxygen composition and the need for microbial population and activity analysis are discussed.

74:05B-022
SOLUTE MOVEMENT THROUGH DISTURBED AND UNDISTURBED SOIL CORES,
Cassel, D.K., Krueger, T.H., Schroer, F.W. and Norum, E.B.
North Dakota State University, Fargo, Department of Soils.
Soil Science Society of America Proceedings, Vol. 38, No. 1, p 36-40, January-February 1974. 9 fig, 19 ref.

Descriptors: *Solutes, *Translocation, *Soil water movement, *Unsaturated flow, *Path of pollutants, Nitrification, Dispersion, Leaching, Chlorides, Nitrates.

Displacement of nitrate and Cl-36 were measured in disturbed (reconstituted horizon by horizon) and undisturbed soil profiles of Aberdeen loam and Beotia loam representing strong and moderate soil structure, respectively. Each soil core was 30 cm in diameter and at least 80 cm high. Mean water content of the undisturbed soil profile was greater and mean bulk density less than the corresponding values for the disturbed cores for each soil. For example, disturbance increased mean water content by 0.07 for Beotia loam with a 0.01 g/cc decrease in bulk density; disturbing Aberdeen decreased bulk density from 1.47 to 1.30 g/cc but increased mean water content only 0.03. The disturbed soils required greater throughout volume of distilled water to displace the solutes and had smaller dispersion coefficients than the undisturbed soils. For a given effluent sample, relative nitrate concentration was consistently greater than relative Cl-36 concentration due to nitrification occurring within both the disturbed and undisturbed soil profiles during the 24-week period.

74:05B-023
NITROGEN MINERALIZATION-WATER RELATIONS IN SOILS,
Stanford, G. and Epstein, E.
Agricultural Research Service, Beltsville, Maryland, Agricultural Environmental Quality Institute.
Soil Science Society of America Proceedings, Vol. 38, No. 1, p 103-106, January-February 1974. 3 fig, 1 tab, 8 ref.

Descriptors: *Nitrogen, *Soil chemistry, *Water chemistry, *Soil moisture,

Moisture tension, Regression analysis, Porosity, Soil texture, Nitrification, Denitrification, Path of pollutants.

The relationships between soil N mineralization, soil water content, and matric suction were studied in nine soils of widely differing chemical and physical properties. Highest N mineralization rates occurred between matric suctions of 1/3 to 0.1 bar, in which range 80% to 90% of the total pore space was filled with water. In the range from optimum soil water content (1/3 to 0.1 bar) to 15 bars, a near-linear relation generally existed between amounts of mineral N accumulated and soil water contents. With increasing dryness, N mineralization continued to decline. Water levels above optimum often reduced mineral N accumulations, presumably because of denitrification. Upon expressing the values for N mineralization (Y) and soil water content (X) for each soil on a relative basis with respect to maximum N mineralized (Y = 100), the regression of Y on X did not differ among soils. Regression coefficients for common (based on covariance) and total regressions, respectively, were 1.07 and 1.02. Corresponding Y-intercepts were -2 and -4. A reasonable approximation of the regression is Y = X.

74:05B-024
MINERAL NITROGEN MOVEMENT INTO SUBSOILS FOLLOWING CONTINUED ANNUAL FERTILIZATION FOR CORN,
MacGregor, J.M., Blake, G.R. and Evans, S.D.
Minnesota University, St. Paul, Department of Soil Science.
Soil Science Society of America Proceedings, Vol. 38, No. 1, p 110-113, January-February 1974. 2 fig, 2 tab, 15 ref.

Descriptors: *Path of pollutants, *Fertilizers, *Nitrates, *Leaching, Nitrification, Denitrification, Ammonia, Nitrogen, Soil water movement, Percolation, Irrigation effects, Tile drainage.

Nitrogen movement was studied in two clay loam soils fertilized in planting for corn (Zea mays L.) for 10 or 15 growing seasons at annual rates of 0, 44.8 or 268.8 kg N/ha. After 10 growing seasons, little NO3-N remained below drainage tile depth in LeSueur clay loam. After 11 growing seasons on untiled Forman clay loam, considerable NO3-N was found at depths to 6 or 7 meters. After 15 years, appreciable nitrate occurred to the 10-m depth. The average rates of movement of the NO3 front for the 10 and the 15-year periods were 1.7 and 1.9 mm/day, respectively. Concentrations of ammonium N were similar under all fertilizer treatments. Annual N additions failed to significantly increase corn grain yields on LeSueur clay loam but significantly increased yields on Forman clay loam.

74:05B-025
NITRIC OXIDE SORPTION BY CALCAREOUS SOILS: II. EFFECT OF MOISTURE ON CAPACITY, RATE, AND SORPTION PRODUCTS,
Miyamoto, S., Prather, R.J. and Bohn, H.L.
Arizona University, Tucson, Department of Soils, Water and Engineering.
Soil Science Society of America Proceedings, Vol. 38, No. 1, p 71-74, January-February 1974. 6 fig, 3 tab, 8 ref.

Descriptors: *Sorption, *Nitrogen, *Waste disposal, Path of pollutants, Air pollutants, Calcareous soils, Soil disposal fields.

At room temperature, the nitric oxide (NO) sorption capacity of calcareous soils increased with the presence of moisture in an air + NO stream (1.5% NO by volume) and in the soils. The largest increase, up to 10-fold or approximately to the acidtitratable basicity of soils, occurred when NO and

$H_2O$ were sorbed simultaneously by initially dry soils from a moist air (humidity $>95\%$) + NO stream. The sorption rates were proportional to the unused portion of the capacity with the rate constants ranging from 0.02 to 0.03 per min for NO and 0.01 to 0.015 per min for $H_2O$ under simultaneous sorption. Initially moist soils sorbed NO from a dry air (humidity $< 5\%$) + NO stream until the soils dried. The rate of NO sorption slowed at initial soil water suctions less than approximately 1 bar. Sorbed NO was recovered as nitrate and reacted with the basicity in moist soils. Less than 20% of the sorbed nitrogen was lost upon heating at 105 deg C for 24 hours.

74:05B-026

### KINETICS OF THE PHOSPHATE INTERACTION WITH CALCITE,

Griffin, R.A. and Jurinak, J.J.
Utah State University, Logan, Department of Soil Science and Biometeorology.
Soil Science Society of America Proceedings, Vol. 38, No. 1, p 75-79, January-February 1974. 6 fig, 1 tab, 19 ref.

Descriptors: *Phosphates, *Calcite, *Sorption, *Adsorption, Thermodynamics, Solubility, Kinetics, Free energy, Soil chemistry, Mineralogy, Water chemistry.

Phosphate interaction with calcite did not proceed in the absence of the calcite surface. The kinetics of interaction could be described by two simultaneous reactions. The first reaction was second-order and was ascribed to the adsorption of phosphate on the calcite surface. The second reaction was first-order and was associated with the surface arrangement of phosphate clusters into calcium phosphate heteronuclei. Solubility criteria show that at low phosphate concentrations the ultimate clacium phosphate surface mineral formed was hydroxylapatite. Desorption kinetics were studied by using an anion exchange resin technique. The desorption process could be described as two simultaneous first-order reactions. The desorption mechanism corresponds to the dissolution of a surface nucleated calcium phosphate mineral, with the second reaction step being the desorption of phosphate from the calcite surface sites. The rate constants for adsorption and desorption were determined at four temperatures between 0 deg C and 40 deg C and were used to compute the activation energies of adsorption and desorption. In addition, the enthalpy of activation, the entropy of activation, and the free energy of activation for both the adsorption and desorption processes were computed.

74:05B-027

### TRANSFORMATION OF IRON IN A WATERLOGGED SOIL AS INFLUENCED BY REDOX POTENTIAL AND PH,

Gotoh, S. and Patrick, W.H., Jr.
Louisiana State University, Baton Rouge, Department of Agronomy.
Soil Science Society of America Proceedings, Vol. 38, No. 1, p 66-71, January-February 1974. 5 fig, 1 tab, 32 ref.

Descriptors: *Iron, *Soil chemistry, *Water chemistry, Oxidation, Hydrogen ion concentration, Reduction(Chemical), Oxidation-reduction potential, Anaerobic conditions.

The distribution of different forms of iron in a waterlogged soil was studied over a wide range of closely controlled redox potential and pH conditions. Increases in water soluble and exchangeable iron were favored by a decrease in both redox potential and pH. The critical redox potentials for iron reduction and consequent dissolution was between +300 mV and +100 mV at pH 6 and 7, and -100 mV at pH 8, while at pH 5 appreciable reduction occurred at +300 mV. The distribution between water soluble and exchangeable iron fractions was highly pH dependent with a decrease in pH at a given redox potential increasing the relative amount of ferrous iron in the soil solution at the expense of that on the exchange complex. A thermodynamic approach to the equilibria between solid phase ferric oxyhydroxide and a water soluble species of iron ($Fe(+2)$) indicated that it was largely governed by the $Fe(+2) - Fe(OH)_3$ system in which the ferric oxyhydroxide was a mixture of goethite and amorphous material.

74:05B-028
QUANTIFICATION OF POLLUTANTS IN AGRICULTURAL RUNOFF,
Dornbush, J.N., Andersen, J.R., and Harms, L.L.
South Dakota State University, Brookings, Department of Civil Engineering.
Environmental Protection Agency, Technology Series Report EPA-660/2-74-005, February 1974. 149 p, 24 fig, 15 tab, 73 ref.

Descriptors: Surface runoff, *Agricultural runoff, Erosion, *Nutrients, Phosphorus, *Nonpoint pollution source, Chemistry, Sediments, *Water pollution sources, Pesticides, Bacteria, *South Dakota, Bioindicators, Rainfall, Snowmelt.

Surface runoff from snowmelt and rainfall is eastern South Dakota was measured during a three year period. The size of the research sites ranged from 7.18 to 18.69 acres, and all sites had crops of corn, oats, pasture or hayland. Composite samples of the runoff were used for various chemical, physical and biological determinations. Runoff samples from 108 snowmelt events and 36 rainfall events were collected. Equipment fabrication and installation resulted in some incomplete data for the initial year, but successful monitoring of each runoff event was accomplished thereafter. Sediment losses were considerably lower than anticipated. Pesticide concentrations were low in both water and sediment samples, and were usually less than the analytical test limits. Coliform and fecal levels were consistently greater than accepted surface water quality criteria. Most of the nutrients were found to be soluble and/or associated with snowmelt runoff.

74:05B-029
THE CHEMISTRY AND TRANSPORT OF LEAD AND CADMIUM IN SOILS,
Jurinak, J.J. and Santilian-Medrano, J.
Utah Water Research Laboratory, Logan.
Available from the National Technical Information Service, Springfield, Virginia as PB-237 497. Research Report No. 18, June 1974, Utah Agricultural Experiment Station, Logan. 121 p, 42 fig, 21 ref, append.

Descriptors: *Heavy metals, *Lead, *Cadmium, *Ion transport, Leaching, Groundwater, Industrial wastes, Soil chemistry, Phosphorus compounds, Soil contamination, Chemical precipitation, Water pollution sources, *Path of pollutants, Model studies.

A one-dimensional transport model for the movement of lead (Pb) and cadmium (Cd) ions through soils under steady state saturated moisture flow was developed. The chemical processes considered were: precipitation and dissolution, ion-pair formation, pH formation, pH flux and adsorption or cation exchange. The transport model was tested by data from laboratory soil columns using three soil types. Initially both chemical equilibrium and kinetic studies were conducted to obtain data necessary for interpretive aspects of the column studies. The main mechanism regulating Pb solubility in the nm-calcareous soils was the precipitation of $Pb_5(PO_4)_3OH$, $Pb_3(PO_4)_2$, and $Pb(OH)_2$. In calcareaous soils, $PbCO_3$ can also precipitate. The solubility of Cd in soils is considerably greater than Pb in the pH range of 5 to 9. At low concentrations of Cd, adsorption by soil is an important mechanism of retention.

At higher concentrations, precipitation of $Cd_3(PO_4)_2$ appears to regulate Cd solubility. The transport model was effective in predicting Cd and Pb movement in soils after the initial 20-25 pore volumes of effluent passed through the soil column. Initial stages of transport were not accurately predicted because of the inability of the model to accurately predict the pH flux when the acid metal slug was added to the soil surface. The mobility of Cd in soil was noticeably greater than that of Pb.

74:05B-030
ECONOMIC EVALUATION OF THE EFFECT OF SELECTED CROP PRACTICES ON NONAGRICULTURAL USES OF WATER,
Onishi, H., Narayanan, A.S., Takayama, T. and Swanson, E.R.
Illinois University, Urbana. Department of Agricultural Economics.
Available from the National Technical Information Service as PB-232 161.
Illinois Water Resources Center, Urbana, Research Report No. 79, March 1974.
58 p, 3 tab, 5 fig, 4 append.

Descriptors: *Water pollution sources, Evaluation, Water quality, Sedimentation, Linear programming, Nitrates, Income, Crops, Illinois, Watersheds (Basins), Path of pollutants.

Cropping systems may have an unfavorable influence on the quality of nearby surface water. Linear programming methods were used to assess the impact of improvements in certain water quality characteristics on economically optimal crop systems. Thus, the effect of crop practices on water quality is analyzed indirectly by assuming that farmers would alter their cropping practices in the most economical way in order to conform to various water-quality constraints. A 1,200-acre watershed was used to illustrate the procedure. Sediment entering the reservoir was treated as a variable constraint on maximization of farm income. Requiring successively lower amounts of sediment to enter the reservoir caused farm income to decrease at an increasing rate. The analysis was enlarged to include a constraint on nitrate in the leachate below the root zone. This phase of the analysis also included a charge for removing at least some of the sediment entering the reservoir. As the nitrate limit on the leachate was lowered, farm income decreased at an increasing rate. The requirement of removal of the sediment by itself had little or no effect on the nitrate concentration in the leachate. Extensions of the procedure for use in other situations are suggested.

74:05B-031
DISTRIBUTION OF CONTAMINANTS IN POROUS MEDIA FLOW,
Marino, M.A.
California University, Davis, Department of Water Science and Engineering.
Water Resources Research, Vol. 10, No. 5, p 1013-1018, October 1974. 1 fig, 22 ref.

Descriptors: *Path of pollutants, Water pollution sources, *Dispersion, *Adsorption, *Fluid movement, Porous media, Saturated flow, Groundwater movement, Mass transfer, Mathematical studies, Equations, Seepage.

A mathematical analysis was presented of simultaneous dispersion and adsorption of a solute within homogeneous and isotropic porous media in steady unidirectional flow fields. The dispersion systems adsorb the solute at rates proportional to their concentration and are subject to input concentrations that vary exponentially with time. Mathematical solutions were developed for predicting the concentration of contaminants in adsorbing and nonadsorbing porous media for prescribed media and fluid parameters.

74:05B-032
DIFFUSION AND DISPERSION IN OPEN CHANNEL FLOW,
Miller, A.C. and Richardson, E.V.
Pennsylvania State University, University Park, Department of Civil Engineering.
Journal of the Hydraulics Division, American Society of Civil Engineers.
Vol 100, No. HY1, Paper 10298, p 159-171. January 1974. 8 fig, 2 tab, 13 ref, append.

Descriptors: *Diffusion, *Dispersion, *Open channel flow, *Path of pollutants, Mixing, Turbulence, Flow resistance

The relationships of lateral turbulent diffusion and longitudinal dispersion coefficients to the parameters that make up the structures of flows were studied experimentally. The resistance to flow for these runs varied from 10.6 to 4.4. The relation for the lateral turbulent diffusion coefficient was not affected by the secondary circulation that was present in all of the flows and is the same as that for a large range of flow conditions. The dispersion coefficient varied with resistance to flow and the average velocity. Longitudinal diffusion, which depends on the turbulence of the flow, was an insignificant factor in the dispersion coefficient as compared to the distribution of the local mean velocity in the lateral and vertical direction.

74:05B-033
LONGITUDINAL DISPERSION IN SATURATED POROUS MEDIA,
Marino, M.A.
California University, Davis Department of Water Science and Engineering.
Journal of the Hydraulics Division, American Society of Civil Engineers,
Vol 100, No HY1, Paper 10296, p 151-157, January 1974. 3 fig, 5 ref, append.

Descriptors: *Path of pollutants, *Groundwater movement, *Dispersion, *Porous media, Equations, Saturated flow, Equations, Water pollution sources, Seepage

Analytical solutions were developed for two problems of longitudinal dispersion within semi-infinite, nonadsorbing, homogeneous, isotropic media in unidirectional flow fields. The source concentrations consist of variable inputs of contaminants. The solutions predict the distribution of contaminants resulting from the variable source concentrations. Two numerical examples are presented.

74:05B-034
EVALUATION OF A SOIL NITRATE TRANSPORT MODEL,
Walter, M.F., Steenhuis, T.S., Bubenzer, G.D., and Converse, J.C.
Wisconsin University, Madison, Department of Agricultural Engineering.
Presented at 1974 Winter Meeting of the American Society of Agricultural Engineers, December 10-13, 1974. Chicago, Illinois. 5 fig, 8 tab, 10 ref.

Descriptors: *Model studies, *Nitrates, Soil water movement, Groundwater, Pollutants.

The potential for groundwater pollution from heavy land applications of dairy manure is a growing concern because manure is being concentrated in smaller areas. The worst conditions in terms of nitrate leaching to the groundwater occur on coarse textured soils in early spring. A computer model was developed specifically for heavy spring application of liquid dairy manure on coarse soils. The model was used to predict nitrate movement from the application of manure on experimental plots on a Plainfield sand and in a Plano silt loam soil column. The computer model was designed to estimate, for specified intervals of soil depth and time after manure application, the delay to initial nitrification of manurial ammonium, ammonium nitrification rate, soil organic nitrogen mineralization rate, nitrate dispersion, nitrate and ammonium content and soil moisture. Precipitation and temperature data, date of manure application, ammonium concentration of liquid manure, and quantity of manure applied must be specified for each particular case. When the model properly simulates nitrate movement through a soil, the results are no better than the input weather data. The

**model depends on the interrelationship between temperature and effective precipitation over a period of several weeks or months. Input weather data should be based on the probability of a sequence of particular weather conditions occurring.**

74:05B-035
NONPOINT AGRICULTURAL POLLUTION: STATUS OF ASSESSMENT METHODOLOGY,
Aleti, A., Chiu, S.Y., and McElroy, A.D.
Midwest Research Institute, Kansas, City, Missouri.
Presented at 1974 Annual Meeting of the American Society of Agricultural Engineers, June 23-26, 1974. Stillwater, Oklahoma. 2 fig, 2 tab, 27 ref.

Descriptors: *Agriculture, Pollutants, Model studies, Water quality, Water pollution control, Water pollution sources.

Nonpoint pollution is considered to be a major deterrent to achievement of water quality goals, and agriculture is a principal source of such pollution. Methods for assessing and quantifying nonpoint pollution are discussed in this paper. The overall basic need is development of comprehensive models which: (1) include all significant pollutants, but can treat each individually; (2) are sensitive to the causes (sources) of pollution and thus can provide the means to develop and assess various pollution control measures and strategies; and (3) recognize interdependencies between pollutants, such as pesticides and sediment, in order to facilitate development of simplified control measures. The truly comprehensive model, in useful form, is probably several years away, so there is a continuing need to construct and use improved less-than-comprehensive models, and to continue the acquisition of knowledge and data needed for progress toward effective overall models.

74:05B-036
SULFUR AND MANGANESE RELEASE FROM SOILS TREATED WITH PRILLED SULFUR-BENTONITE,
Lindell, D.L. and Sornson, R.C.
Missouri University, Clinton, Department of Agronomy.
Soil Science Society of America Proceedings, Vol. 38, No. 2, p 368-372, March-April, 1974. 3 fig, 2 tab, 10 ref.

Descriptors: Fertilization, Fertilizers, Sulfated, Sulfur, Hydrogen, Soil properties, Soils.

Seven Nebraska soils were used to compare prilled sulfur and sulfur-bentonite formulation in regard to the amount of sulfate-sulfur, manganese and hydrogen released to a leaching solution after successive incubations. Also the effects of sulfur fertilizer granule concentrations in the soil were studied. Generally, the amount of sulfate-sulfur and manganese and the pH values in leachates from the columns containing sulfur-bentonite were not different from those from columns containing prilled sulfur. Differences among soils could not be explained on the basis of measured soil properties. The relationships between the amounts of sulfate-sulfur or manganese released and percentage sulfur or sulfur-bentonite in the soil were generally quadratic with the maximum release occurring in the range 30 to 60% sulfur. The greatest amount of sulfur released per gram sulfur added occurred at the lowest sulfur to soil ratio studies.

74:05B-037
A STEADY-STATE MODEL OF ISOTOPIC FRACTIONATION ACCOMPANYING NITROGEN TRANSFORMATIONS IN SOIL,
Shearer, G., Duffy, J., Kohl, D.H., and Commoner, B.
Washington University, St.Louis, Missouri, Center for the Biology of Natural Systems.
Soil Science Society of America Proceedings, Vol. 38, No. 2, p 315-322, March-April, 1974. 3 fig, 17 ref.

Descriptors: Mathematical studies, Nitrification, Ammonification, Nitrogen.

A steady-state mathematical model of isotopic fractionation accompanying certain nitrogen transformations in soil is developed. The model takes into account ammonification, nitrification, and immobilization; and predicts that the 15N/14N ratios of nitrate and ammonium ion depend in part upon the ratio of the rates of immobilization to nitrification under field conditions is unlikely to be the same as under the conditions of laboratory incubation experiments. Therefore, this prediction provides a possible explanation for differences observed between the 15N/14N ration of nitrate extracted from soil cores and that of nitrate released during laboratory incubation of the same soils. The model described is ammenable to experimental test. If verified, an expanded version of the model may be a useful aid in the study of nitrogen transformations in the field.

74:05B-038
GROUND-WATER QUALITY STUDY,
White, N.F. and Sunada, D.K.
Texaco Corporation
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 100, No. IR3, p 277-292, September, 1974. 6 fig, 4 tab, 9 ref, 2 append.

Descriptors: *Groundwater, Groundwater recharge, Water pollution, Water pollution sources, Water quality, Colorado, Fertilizer, Leaching, Hydrology.

Because of increasing contamination of groundwater in Colorado, a field study was initiated of a groundwater basin showing degradation of water quality. The basin studied was Severance Basin, located about 2 miles (3.2 km) northeast of Windson, Colorado. In this basin, the primary source of groundwater is percolation from irrigation. Increasing contamination in the basin was attributed to several factors: (1) leaching of applied fertilizer; (2) drainage from silage pits and feed lots; (3) percolation of contaminants from oil field brine pits; (4) irrigation; and (5) geologic contamination of the aquifer.

74:05B-039
IMPACTS OF COLORADO RIVER SALINITY,
Valantine, V.E.
Colorado River Board of California, Los Angeles.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 100, No. IR4, p 495-510, December, 1974. 6 tab, 9 ref.

Descriptors: Salinity, Saline soil, Saline water, Colorado River, Colorado River basin, Salts.

Unless measures are taken to control the salinity of the Colorado River, the average annual salinity at Imperial Dam will increase from a current level of 880 mg/l (1968-1972) to 1,210 mg/l in 2000, an increase of 330 mg/l: This increase would cause deleterious impacts on irrigation and urban water users in the states of Arizona, California, and Nevada amounting to about $580,000,000/yr in the year 2000. The unit values of salinity detriments were found to be $0.25/acre-ft/mg/l ($0.00002 cu m/mg/l) and $0.275/acre-ft/mg/l ($0.000022/cu m/mg/l) for the years 1980 and 2000, respectively. These detriments indicate that the stake the people of the Colorado River Basin have in measures to control the river's salinity.

74:05B-040
OUTLET DRAINAGE IN ONTARIO--A METHODOLOGICAL EXPLORATION,
Kettel, G.A. and Day, J.C.
Kilborn Engineering, Ltd., Toronto, Ontario, Canada.
Journal of Environmental Management, Vol. 2, No. 4, p 331-349, October 1974. 2 fig, 4 tab, 38 ref.

Descriptors: *Drainage effects, *Drainage practices, *Drainage water, Biological communities, Social aspects, Hydrologic aspects, Hydrologic systems.

There are considerable data which indicate that significant direct agricultural benefits are normally induced by land drainage. However, comparatively little is known concerning the indirect effects of this popular land management practice on hydrological, biological, and social systems. This article focuses on outlet drains in Ontario which permit rapid removal of water from field tile systems to natural water courses. Based on a review of the ability of existing hydrologic knowledge to predict offsite drainage effects, it shows that little research has been directed to this question. Legal and institutional arrangements to cope with such unforeseen changes in Ontario are examined and both are found to be inadequate to prevent these kinds of damages.

74:05B-041
SOURCES AND TRENDS IN WASTE WATER LOADINGS TO THE SAN FRANCISCO BAY REGION,
Breslaw, J.A.
Sir George Williams University, Montreal, Quebec, Canada, Department of Economics,
Water Resources Research, Vol. 10, No. 6, p 1085-1089, December 1974. 3 fig, 1 tab, 9 ref.

Descriptors: *Waste water (pollution), *Pollutant identification, *Pollutants, Water quality, Water pollution, Water pollution sources.

This study uses data obtained from the U.S. Army Corps of Engineers Permit Program and self-monitoring data from the regional water quality control board in an analysis of waste discharges to watercourses in the San Francisco Bay Region. The analysis shows that the majority of these discharge loads can be attributed to a few sources. Trend analysis showed that the BOD load has declined in relation to the quantities discharged in the early 1960's. Nutrients, however, have increased at an annual rate of about 4% since the early 1960's.

74:05B-042
A SURVEY OF THE BORON CONTENT OF CERTAIN WATERS OF THE GREATER LONDON AREA USING A NOVEL ANALYTICAL METHOD,
Matthews, P.J.
Directorate of Scientific Services, Anglian Water Authority, Diploma House, Huntingdon.
The Journal of the International Association on Water Pollution Research, Vol. 8, No. 12, p 1021-1028, December, 1974. 1 fig, 7 tab, 23 ref.

Descriptors: *Boron, *Aquatic environment, *Sewage, *Sewage effluents, *Analytical techniques, Water quality, Water pollution.

Natural levels of boron, (as boric acid), in the aquatic environment have been raised artificially in certain areas by sewage effluents. Boron is present in sewage effluent by virtue of the use of sodium perborate as a whitener in washing powders. A novel analytical method based on the solvent extraction of ferroin borodisalicylate was used in a survey of various types of sewage, sewage effluent and natural waters in the London area. The method was found to be satisfactory under all conditions. The data obtained will be useful in water resource planning and indicated that the concentration of boron in a watercourse may be used, under certain conditions, to determine the degree of dilution of sewage effluent in that watercourse.

74:05B-043
PHYSICAL AND CHEMICAL QUALITY OF AGRICULTURAL LAND RUNOFF,
Harms, Leland L., Dornbush, James N., and Anderson, John R.
South Dakota State University, Brookings.
Journal of the Water Pollution Control Federation, Vol. 46, No. 11, p. 2460-2470, November, 1974. 3 fig, 7 tab, 23 ref.

Descriptors: *Runoff, *Water chemistry, Water pollution, Water pollution sources, Water properties, Water quality, Erosion, Rainfall, Snowmelt, Phosphorus, Nutrients.

Considerable quantities of nutrients were present in the agricultural runoff, and these would seem to have important implications regarding the possible occurrence of eutrophic conditions in water impoundments. Nutrient losses averaged about 1 lb/yr/acre (1.12 kg/yr/ha) for nitrogen and about 0.2 lb/yr/

acre (0.2 kg/yr/ha) for phosphorus. The nutrient form is also of consequence. Most of the annual nutrient load for the area studied came from snowmelt runoff, and a large percentage was soluble. Soil conservation practices will probably not be effective measures for retarding lake eutrophication from the nutrients in agricultural runoff. The annual soil losses were much lower than expected, most of the sediment originating from cultivated fields. The bulk of the soil losses, as well as losses of those constituents associated with the soil, occurred during short duration, high intensity rain storms. Almost all of the soil lost during the study may be attributed to rainfall runoff.

74:05B-044

### DIFFERING SENSITIVITY OR CORN AND SOYBEAN PHOTOSYNTHESIS AND TRANSPIRATION TO LEAD CONTAMINATION,

Bazzaz, F.A., Rolfe, G.L. and Windle, P.
Illinois University, Urbana.
Journal of Environmental Quality, Vol. 3, No. 2, p 156-158, April-June, 1974.
3 fig, 15 ref.

Descriptors: *Heavy metals, *Pollution, *Crop response, *Lead, Corn, Soybean, Photosystems, Transpiration.

Corn plants grown in media containing a range of Pb concentrations supplied as PbCl(2), showed decreased net photosynthesis and transpiration with increasing Pb treatment levels. At lower Pb treatment levels, corn appears to be more sensitive than soybeans. However, at high treatment level (62.5-250 mg/plant) soybeans are more sensitive than corn. At 250 mg Pb/plant in the medium, photosynthesis is only 10% of maximum in soybeans but 47% in corn, even though corn Pb tissue content is much higher than that of soybeans. Transpiration exhibited similar trends to photosynthesis suggesting that, especially in corn, an appreciable part of the inhibition of the two processes is related to increased stomatal resistances with increased Pb concentrations. Lead accumulation trends were similar at treatment levels of 0 to 62.5 mg/plant but were slightly different at higher levels. The total amount of Pb accumulated was higher in corn than in soybeans. Maximum accumulation in both species occurred at 62.5 mg Pb/plant.

74:05B-045

### OCCURRENCE OF 2,4,5-T AND PICLORAM IN SURFACE RUNOFF WATER IN THE BLACKLANDS OF TEXAS,

Bovey, R.W., Burnett, E., Richardson, C., Merkle, M.G., Jr., and Baur, J.R.
United States Department of Agriculture, College Station, Texas, Agricultural Research Service.
Journal of Environmental Quality, Vol. 3, No. 1, p 61-64, January-March, 1974.
8 tab, 12 ref.

Descriptors: *Herbicides, Watersheds (basins), Watershed management, Runoff, Range management.

This investigation was conducted to determine the concentration of 2,4,5-T and picloram in surface runoff water that may move from herbicide sprayed pastures and rangeland to untreated areas as a result of each major rainfall following treatment. A 1:1 mixture of the triethylamine salts of 2,4,5-T + picloram was sprayed 5 times at 1.12 kg/ha every 6 months on a native-grass pasture watershed. Soil, grasses and runoff water were analyzed periodically following herbicide treatment. Herbicide content in the Houston Black clay from May 1970 to May 1972 remained low (o to 238 ppb). Herbicide content on grass was high (50 to 70 ppm) immediately after treatment, but degraded rapidly thereafter. Plant "washoff was the main source of herbicide detected in runoff water. Concentration of herbicide was moderately high (400 to 800 ppb) if heavy rainfall occurred immediately after treatment, but low (<5 ppb) if major storms occurred 1 month or longer after treatment.

74:05B-046
NUTRIENT LOSSES FROM FERTILIZED GRASSED WATERSHEDS IN WESTERN NORTH CAROLINA,
Kilmer, V.J., Gilliam, J.W., Lutz, J.F., Joyce, R.T. and Eklund, C.D.
Tennessee Valley Authority, Muscle Shoals, Alabama, Soils and Fertilizer Research Branch.
Journal of Environmental Quality, Vol. 3, No. 3, p 214-218, July-September, 1974. 1 fig, 7 tab, 29 ref.

Descriptors: *Nutrients, *Nitrogen, *Phosphorus, *Potassium, Runoff, Water quality, Groundwater, Drainage, Fertilizers, Fertilization, North Carolina.

The transport of plant nutrients in drainage waters from two steeply sloping, differentially fertilized, grassed watersheds located in western North Carolina was determined over a 4-year period. Watershed No. 1 has a drainage area of 1.89 ha, No. 2, 1.48 ha. The dominant slopes on both watersheds are 35 to 40%. During this period, watershed No. 1 received a total of 112-48-24 kg N-P-K/ha; watershed No. 2 received 448-192-24 kg N-P-K/ha. Average annual measured N losses were 3.28 and 12.08 kg/ha for watershed No. 1 and watershed No. 2, respectively; NO(3)-N comprised 70% and 85% of the total N lost in discharge waters from the two watersheds. Total N lost over the 4-year period from each watershed was 6 to 10% of the fertilizer N applied. Annual P losses were negligible, amounting to 0.15 kg/ha from watershed No. 1 and 0.27 kg/ha from watershed No. 2. Measured K losses averaged 3.99 and 5.83 kg/ha annually; S losses were 1.92 and 2.54 kg/ha from watershed No. 1 and watershed No. 2 respectively.

74:05B-047
LAND SURFACE EROSION AND RAINFALL AS SOURCES OF STRONTIUM-90 IN STREAMS,
Menzel, R.G.
United States Department of Agriculture, Durant, Oklahoma, Agricultural Research Service, Water Quality Management Laboratory.
Journal of Environmental Quality, Vol. 3, No. 3, p 219-223, July-September, 1974. 4 fig, 2 tab, 23 ref.

Descriptors: *Runoff, *Erosion, *Strontium, *Streams, Water quality, Pollution, Radioactivity, Pesticides, Correlation analysis.

Strontium-90 concentrations in streams from 1958 to 1967 reflected the changing concentrations in rainfall and accumlation on the land surface. Correlation analysis of data from nationwide sampling networks shows that the Sr-90 concentration in streams was accounted for, on the average, by 1.7% of the rainout 2 months earlier, and annual erosion of 0.58% of the accumulated Sr-90 on the land surface. Direct runoff of Sr-90 in preceding rainfall was highest, 2.0 to 2.2%, in the north central and eastern United States, ranging down to no measurable direct runoff in the southwestern United States. Annual erosion of Sr-90 from the land surface ranged from 0.75% in the Ohio River Basin to 0.17% in the Missouri River Basin. If one allows for differences in time and area of application, these results for land surface erosion indicate the potential movement of persistent, strongly adsorbed pesticides from large land areas.

74:05B-048
UPTAKE OF INORGANIC MERCURY BY BED SEDIMENTS,
Kudo, A., and Hart, J.S.
Journal of Environmental Quality, Vol. 3, No. 3, p 273-278, July-September, 1974. 7 fig, 21 ref.

Descriptors: *Mercury, Rivers, Sediments, Kinetics, Water quality, Water pollution.

The kinetics of uptake of inorganic mercury as mercuric chloride by a variety of freshwater river sediment types typical of Ottawa River sediments were studied to determine the influence of mercury concentration in water, hydrodynamic effects, sediment depth, aerobic or anaerobic conditions, and two types of water. Uptake appears to depend strongly on concentration of mercury in water and water velocity, and not on sediment depth or water type. No significant difference in uptake rates was observed between aerobic and anaerobic conditions during the 10 days studied.

74:05B-049
PHOSPHORUS ASSOCIATED WITH SEDIMENTS IN IRRIGATION AND DRAINAGE WATERS FOR TWO LARGE TRACTS IN SOUTHERN IDAHO,
Carter, D.L., Brown, M. J., Robbins, C.W., and Bondurant, J.A.
Snake River Conservation Research Center, Kimberly, Idaho.
Journal of Environmental Quality, Vol. 3, No. 3, p 287-291, July-September, 1974. 5 tab, 18 ref.

Descriptors: *Phospnorus, Irrigation water, Drainage water, Irrigation practices, Erosion, Sediments, Water quality, Water pollution.

Phosphorus was measured in irrigation and surface drainage waters for two large irrigation tracts, and inorganic, water-soluble PO(4)-P and total P inputs and outputs were computed. The present irrigation practices on both irrigation tracts conserve P by removing more P from the Snake River in irrigation water than is returned in drainage water. Even greater P conservation could be attained by implementing new practices. Approximately 90% of the P in waters diverted to irrigate the Northside Tract remained in the tract. About 50% of the amount diverted remained in the Twin Falls Tract. Particle size segregation takes place in some drainage streams and the finer sediments returning to the river contain higher total and NaHCO(3)-extractable P concentrations than the soils from which they were eroded.

74:05B-050
NITRATE AND CHLORIDE MOVEMENT IN THE PLAINFIELD LOAMY SAND UNDER INTENSIVE IRRIGATION,
Endelman, F.J., Keeney, D.R., Gilmour, J.T., and Saffigna, P.G.
Wisconsin University, Madison, Department of Chemical Engineering.
Journal of Environmental Quality, Vol. 3, No. 3, p 295-298, July-September, 1974. 5 fig, 2 tab, 11 ref.

Descriptors: *Fertilization, *Fertilizer, *Nitrates, *Nitrogen, *Leaching, Irrigation practices, Irrigation, Groundwater, Pollution, Water quality, Soil properties, Lysimeters, Chlorides.

A field experiment to evaluate leaching under intensive irrigation was conducted over an 11-day period on a Plainfield loamy sand fertilized with KNO(3) and KCL. The NO(3)-N and Cl concentration in soil profile and lysimeter leachate samples collected daily were determined. Under the conditions of this experiment 2.5 cm of water moved about 19 cm in the surface and 28 cm in the subsurface soil. Chloride concentrations in the profiles were similar to those of NO(3)-N. Movement of NO(3)-N and Cl was 15 to 20 cm/day under 2.5 cm daily water application. The results show that rainfall and/or irrigation, can rapidly move NO(3)-N beyond the rooting zone of this soil.

74:05B-051
PLANT NUTRIENT LOSSES FORM TILE-OUTLET TERRACES,
Hanway, J.J. and Laflen, J.M.
Iowa State University, Ames, Department of Agronomy.
Journal of Environmental Quality, Vol. 3, No. 4, p 351-356, October-December, 1974. 3 fig, 4 tab, 13 ref.

Descriptors: *Nutrient removal, *Nutrients, *Phosphorus, Tile drainage, Sediment, Nitrogen, Nitrification, Sulfur, Runoff, Fertilizer, Fertilization.

Plant nutrient losses in runoff water from four tile-outlet terrace systems in Iowa and in tile drainage from two of the systems were measured annually from April to November over a 3-year period. Soluble P concentrations in surface runoff were related to available P in the surface soils, and concentrations in tile drainage were related to available P in the subsoils. Concentrations of inorganic N varied widely among locations, but were relatively constant at a location. Average annual inorganic N concentrations in surface runoff were 4 ppm or less at three of the four sites and 11 ppm at one site. Concentrations of inorganic N and sulfate S were similar and were lower in surface runoff than in tile drainage. There was no relation between the amounts of fertilizer applied and plant nutrient losses or concentrations in runoff or drainage water.

74:05B-052
PRECIPITATION NITROGEN CONTRIBUTION RELATIVE TO SURFACE RUNOFF DISCHARGES,
Schuman, G.E. and Burwell, R.E.
United States Department of Agriculture, Lincoln, Nebraska.
Journal of Environmental Quality, Vol. 3, No. 4, p 366-369, October-December, 1974. 1 fig, 4 tab, 12 ref.

Descriptors: *Nitrates, *Ammonia, Runoff, Watershed management, Water quality, Precipitation, Water pollution, Nutrient removal.

Ammonia and nitrate concentrations in precipitation and surface runoff from two adjacent watersheds, fertilized at 168 and 448 kg N/ha, respectively, were studied to determine the relative contributions of precipitation N in relation to surface runoff N discharge. The data show that 69% of the N discharged by surface runoff from the sampled events could be accounted for by precipitation-originated N on the watershed fertilized at 168 kg N/ha, whereas 53% of the N discharged from the watershed fertilized at 448 kg N/ha could be a attributed to N originating in the precipitation. However, the data indicate that, on an annual basis, the surface runoff N discharge accounts for only 20% of that in the total incoming precipitation. This difference can be accounted for by precipitation intensity or duration that did not cause runoff, absorption of $NH(4)$-N by the soil material, or leaching of $NO(3)$-N into the soil profile.

74:05B-053
FATE OF INSECTICIDES IN AN IRRIGATED FIELD: AZINPHOSMETHYL AND TETRADIFON CASES,
Yaron, B. Bielorai, H., and Kliger, L.
Institute of Soils and Water, ARO, Volcani Center, Bet Dagan, Israel, Division of Soil Residue Chem.
Journal of Environmental Quality, Vol. 3, No. 4, p 413-417, October-December, 1974. 7 fig, 7 ref.

Descriptors: *Pesticides, *Pesticide removal, *Pesticide residues, *Leaching, Irrigation practices, Soil water movement, Potato.

The fates of an organophosphorus and an organochlorine insecticide in an irrigated potato field on a loessial sierozem soil were studied. Two amounts of irrigation water (5538 and 4015 cu m/ha) were applied; the kinetics of persistence and the movement downward of the two pesticides were followed during the irrigation season. The azinphosmethyl was not transported deeply into the soil by the irrigation water, and it disappeared from the field 30 days after application. The tetradifon was found in trace amounts in the deeper layer of the soil and was persistent throughout the irrigation season. The pesticides' persistence was not affected by the irrigation treatments; however, tetradifon transport into the soil was affected by the amount of water applied. Residues of tetradifon were found in the potato peel.

74:05B-054
NITROGEN CONTENT OF SHALLOW GROUND WATER IN THE NORTH CAROLINA COASTAL PLAIN,
Gilliam, J.W., Daniels, R.B., and Lutz, J.F.
North Carolina State University, Department of Soil Science.
Journal of Environmental Quality, Vol. 3, No. 2, p 147-151, April-June, 1974.
2 fig, 2 tab, 14 ref.

Descriptors: *Nitrates, *Nitrogen, Groundwater, *Denitrification, Cultivation, Wells, Aquifer, North Carolina.

The NO(3)-N and NH(4)-N concentrations in shallow (<3 m) ground water under a range of soil types, drainage conditions, and type of crop grown were monitored. The NO(3)-N levels were always low (1 ppm or less) in ground water under wooded areas. The concentrations were somewhat higher under cultivated fields with the levels usually being 1 to 5 ppm although several values in the range of 10 to 20 ppm were recorded. The concentrations in all wells were always higher during the winter months. There seemed to be no relationship between cultivated crop and NO(3)-N in the ground water. The NO(3)-N concentration was almost always higher in the middle of the field than was toward the edge of the field. It is suggested that denitrification is responsible for this decrease. Based upon the characteristics of the surface sediments, it is concluded that very little of the NO(3)-N present in the shallow ground water moves into deep aquifers in any area of the North Carolina Coastal Plain. However, the amount of NO(3)-N that moves through the surficial sediments to the streams probably varies with location and characteristics of the confining beds.

# Section XVIII

## WATER QUALITY MANAGEMENT AND PROTECTION

### EFFECTS OF POLLUTION (Group 05C)

74:05C-001
THE PHOSPHORUS STATUS OF EUTROPHIC LAKE SEDIMENTS AS RELATED TO CHANGES IN LIMNOLOGICAL CONDITIONS--TOTAL, INORGANIC AND ORGANIC PHOSPHORUS,
Wildung, R.E., Schmidt, R.L. and Gahler, A.R.
Battelle-Pacific Northwest Laboratory, Richland, Washington.
Journal of Environmental Quality, Vol. 3, No. 2, p 133-138, April-June 1974. 2 fig, 3 tab, 19 ref.

Descriptors: Sampling, *Phosphorus, *Sediments, *Eutrophication, *Lakes, Carbon, *Nitrogen, Organic matter, Phytoplankton, Runoff, Biological communities, Surface waters, Turbidity, Water pollution effects, *Oregon, *Lake sediments.

The role of sediments as a source of phosphorus to lake waters and the factors which may influence sediment phosphorus release were studied. Changes with time in the phosphorus status of noncalcareous sediments of a eutrophic lake were related to changes in sediment carbon and nitrogen, surface water composition, pH, temperature, and phytoplankton growth. Sediment phosphorus status and the relationship of these changes to limnological conditions differed with locations in the lake. Changes in sediment composition were greatest in a bay which received agricultural runoff in the early spring, additional nutrients apparently providing the initial impetus for increased surface water biological activity. This was reflected in increased surface water organic carbon and nitrogen, turbidity, and phytoplankton growth. At this location, total sediment phosphorus, carbon, and nitrogen decreased during the late spring and early summer, corresponding to the period of exponential growth of the lake phytoplankton population. Results indicate that sediment inorganic phosphorus is directly related to the biological productivity of the surface waters, and in at least one location, sediments serve as a significant source of phosphorus to these waters supporting increased biological growth.

74:05C-002
ECONOMIC DAMAGES FROM RESIDENTIAL USE OF MINERALIZED WATER SUPPLY,
Tihansky, D.P.
Environmental Protection Agency, Washington, D.C., Economic Analysis Division.
Water Resources Research, Vol. 10, No. 2, p 145-154, April 1974. 8 fig, 5 tab, 38 ref.

Descriptors: *Water quality, *Domestic water, *Damages, Public health, Scaling, Corrosion, Economics, Abrasion, *Costs, Plumbing, *Computer programs, Clogging.

Household appliances and personal items in contact with water supplied municipally or from private sources are subject to physical damages from chemical and other constituents of the water. Economic losses are calculated for a typical household and aggregated to the national and individual state levels. The types of physical damages expected and the associated water quality determinants were identified, and the physical effects were then translated into economic losses. Damage functions were formulated to predict likely impacts of water quality changes on each household unit affected. A computer program based on these functions was designed to estimate total damages per typical household and to aggregate them over selected regions. The program was applied to state-by-state data describing water supply sources and socioeconomic parameters. Total annual damages to U.S. residents in 1970 were estimated to be in the range $0.65-$3.45 billion, the mean being $1.75 billion. The mean translates to $8.60 per person annually. States having the highest total damages were California ($230 million) and Illinois ($164 million). On a per capita basis, Arizona ($22.53) and New Mexico ($18.58) ranked highest, whereas South Carolina ($1.15) and Oregon ($1.73) were at the other end of the spectrum. When per capita damages were compared by source of water supply, private wells were highest at an average of $12.34, treated groundwater was next at $11.20, and treated surface water was last at $5.83.

74:05C-003
A SOLUTION OF THE INORGANIC CARBON MASS BALANCE EQUATION AND ITS RELATION TO ALGAL GROWTH RATES,
Kelly, M.G., Church, M.R., and Hornberger, G.M.
Virginia University, Charlottesville, Department of Environmental Sciences.
Water Resources Research, Vol. 10, No. 1, p 493-497, 1974. 2 fig, 1 tab, 18 ref.

Descriptors: *Equations, *Carbon, *Carbon dioxide, *Algae, Mathematical studies, Growth rates, Biological communities, Productivity, Groundwater, Rivers, Lakes, Biomass, Eutrophication.

It is interesting to know under what natural conditions carbon dioxide concentrations might be low enough to influence algal growth rates. Even if low carbon concentrations do not prevent cultural eutrophication, they could well influence the relative growth of different species. Equations describing the concentrations of the various inorganic carbon species in relation of pH and alkalinity may be combined with a chemical mass balance equation describing the rate of change of total inorganic carbon in a river due to photosynthesis, respiration, accrual from groundwater, and exchange with the atmosphere. The mass balance equation is solved to give carbon dioxide concentration throughout the day. Without accrual of groundwater the carbon dioxide concentration must lie in the range where it will influence growth rate of some plant species, but groundwater input prevents this situation in most rivers. In lakes, groundwater input and exchange with the aphotic zone may prevent the influence of carbon dioxide on algal growth rates. In waters with little groundwater input or little vertical mixing the carbon dioxide concentration may influence relative growth rates of species and thus the community composition but probably not the total plant biomass produced.

74:05C-004
INORGANIC NITROGEN REMOVAL IN A COMBINED TERTIARY TREATMENT - MARINE AQUACULTURE SYSTEM - II. ALGAL BIOASSAYS,
Goldman, J.C., Tenore, K.R., and Stanley, H.I.
Woods Hole Oceanographic Institution, Massachusettes
Water Research, Vol 8, No 1, p 55-59, 1974. 3 fig, 2 tab, 9 ref.

Descriptors: *Waste water treatment, *Bioassays, Sampling, *Tertiary treatment, Discharge (Water), *Nitrogen, *Algal control, Waste water (Pollution), Coasts

Algal bioassays, conducted on samples from various conponents of the combined tertiary treatment-marine aquaculture process, demonstrated that nitrogen removal is necessary to prevent increasing the algal growth potential of coastal marine waters receiving wastewater discharges. When nitrogen was removed from secondarily treated domestic wastewater, the wastewater in varying dilutions with seawater could not support more algal growth than the seawater alone. By adding nitrogen back to the treated wastewater the algal growth potential was increased to that of the untreated wastewater. This was demonstrated by assaying samples containing both artificially added nitrogen and nitrogen regenerated by oysters. Assays of the effluent from the seaweed system showed that the removal of regenerated nitrogen reduced the algal growth potential to that of natural seawater.

74:05C-005
ENVIRONMENTAL ASPECTS OF AQUATIC PLANT CONTROL,
Bartley, T.R. and Gangstad, E.O.
Bureau of Reclamation, Denver, Colorado, Environmental Science Section,
Division of General Research.
Journal of the Irrigation and Drainage Division, American Society of Civil
Engineers, Vol. 100, No. IR3, p 231-244, September, 1974. 4 fig, 2 tab, 17
ref.

Descriptors: Aquatic environment, Aquatic life, Aquatic plants, Aquatic weed control, Aquatic weeds, Herbicides.

Detailed studies on the environmental aspects of aquatic control with aquatic herbicides do not preclude their use when properly selected and properly applied. Residues in the water under the conditions stated, do not preclude the use of this water for irrigation of crop plants or potable use of the water.

74:05C-006
IMPACTS OF COLORADO RIVER SALINITY,
Valantine, V.E.
Colorado River Board of California, Los Angeles.
Journal of the Irrigation and Drainage Division, American Society of Civil
Engineers, Vol. 100, No. IR4, p 495-510, December, 1974. 6 tab, 9 ref.
(See 74:05B-039)

# WATER QUALITY MANAGEMENT AND PROTECTION

## WASTE TREATMENT PROCESSES (Group 05D)

74:05D-001
SITE EVALUATION AND DESIGN OF SEEPAGE FIELDS,
Healy, K.A. and Laak, R.
Connecticut University, Storrs, Department of Civil Engineering.
Journal of the Environmental Engineering Division, American Society of Civil Engineers, Vol. 100, No. EE5, Proceedings Paper 10882, p 1133-1146, October 1974. 7 fig, 2 tab, 15 ref, 3 append.

Descriptors: *Seepage, *Groundwater recharge, *Infiltration, *Septic tanks, *Sewage disposal, *Domestic wastes, *Connecticut, Flow nets, Seepage control, Disposal, Percolation, Water pollution sources, Water pollution, Absorption, Permeability, Waste water disposal, Subsurface drainage, Tiles, Hydraulic conductivity, Effluents, Environmental engineering.

A reevaluation of previous work by others indicated that soil can absorb septic tank effluent indefinitely if the application rate is kept below a certain level, which is a function of soil permeability. This long-term acceptance rate is independent of whether the soil is continuously or intermittently flooded, and varies from approximately 0.3 gpd/sq ft (0.01 m/day) for clay loam and silt to approximately 0.8 gpd/sq ft (0.03 m/day) for sand. Study of the groundwater flow pattern below a seepage field showed that it is, in many cases, the hydraulic conducitivty of the ground surrounding the field, as determined by the external water table, soil permeability, and impervious strata, that controls the size of the field required. These three factors were determined by a test pit dug at seven sites in the Mansfield, Connecticut area. Pit permeability tests were developed and results compared favorably with tube sample permeameter tests. Based on the information obtained, a chart was prepared to aid in designing a seepage field. Two design examples were included.

74:05D-002
INORGANIC NITROGEN REMOVAL IN A COMBINED TERTIARY TREATMENT - MARINE AQUACULTURE SYSTEM -- I. REMOVAL EFFICIENCIES,
Goldman, J.C., Tenor, K.R., Ryther, J.H. and Corwin, N.
Woods Hole Oceanographic Institution, Massachusettes
Water Research, Vol 8, No 1, p 45-54, 1974. 5 fig, 6 tab, 34 ref.

Descriptors: *Recycling, Water conservation, Water pollution treatment, *Water reuse, Sewage treatment, *Tertiary treatment, *Food chains, *Food webs, Ecosystems, Algae, Oysters, Nitrogen, *Waste water treatment, *Phosphorus.

The transformation of nitrogen and phosphorus were observed during the Summer and Fall of 1972 in a prototype process consisting of growth systems for marine algae, oysters, and seaweed, joined in series and fed secondarily-treated waste-water diluted 1:4 with seawater for 11 weeks. During this time 95% of the influent inorganic nitrogen was removed by algal assimilation. The oysters in turn removed 85% of the algae, but regenerated as soluble ammonia 16-18% of the nitrogen originally bound in the algal cells. All of the regenerated nitrogen was removed in the seaweed system so that the total inorganic nitrogen removal efficiency of the system was 95%. Phosphorus removal was not nearly as complete as only 45-60% was removed. The process has the capability of being expanded to include additional trophic levels in an integrated and highly controlled food chain system to serve the dual function of tertiary wastewater treatment and waste recycling through the production of shellfish and seaweeds.

74:05D-003
THE DEVELOPMENT OF A CENTER PIVOT WASTEWATER IRRIGATION MACHINE,
Hall, G.W.
Metropolitan Sanitary District of Greater Chicago, Canton, Illinois.
Presented at 1974 Winter Meeting of the American Society of Agricultural Engineers, December 10-13, 1974. Chicago, Illinois. 5 fig, 2 tab, 7 ref.

Descriptors: *Sprinkler irrigation, *Waste water disposal, Application methods, Application equipment, Irrigation practices, Irrigation water, Irrigation, Irrigation systems.

The center pivot irrigation industry continues to improve its product each year. Problem areas highlighted by a testing program were corrected and incorporated into the manufacturers model changes for the next year. Probably the most important difference between a conventional center pivot irrigation machine and a wastewater center pivot irrigation machine is the spray bar concept. The low operating pressure requirement provides a lower operating cost because of lower pumping costs. However, the high instantaneous application rate of the spray bar concept limits its application to areas where the soil has a high intake rate if surface runoff is minimized. The center pivot wastewater irrigation machine will continue to be a modified conventional center pivot irrigation machine until the wastewater market developes to the point where the center pivot industry begins to conduct research and development programs. The goal of the wastewater industry and the agricultural industry is the same and that is to have an economical, dependable irrigation machine.

74:05D-004
NITRIFICATION RATE IN BIOLOGICAL PROCESSES,
Huang, C.S. and Hopson, N.E.
Metcalf and Eddy, Incorporated, Boston, Massachusetts.
Journal of the Environmental Engineering Division, Vol. 100, No. EE2, p 409-422, April 1974. 3 fig, 78 ref, 2 append.

Descriptors: *Nitrification, Rates, Sanitary engineering, Biological properties, Laboratory tests.

A review of literature concerning the nitrification process shows a diverse opinion as to the reaction rate equation for the process. Four reaction rate equations are reviewed and an experimental study performed to determine the correct equation. From the initial ammonia nitrogen concentration and the contact time studies the nitrification process was shown to follow a zero-order reaction. This conclusion is in disagreement with some of the reviewed literature. However, many experimental and evaluation problems may cause researchers to assume first-order reaction rates in their nitrification studies. The expression "percent removal" or "percent remaining" usually used in BOD reactions is not a meaningful way to evaluate the reaction rate. A small change in pH caused by the H+ ions released from the nitrification process also may affect the results of nitrification studies.

## WATER QUALITY MANAGEMENT AND PROTECTION

### WATER QUALITY CONTROL (Group 05G)

74:05G-001
EVALUATION OF IRRIGATION SCHEDULING FOR SALINITY CONTROL IN GRAND VALLEY,
Skogerboe, G.V., Walker, W.R., Taylor, J.H. and Bennett, R.S.
Colorado State University, Fort Collins, Department of Agricultural Engineering.
Environmental Protection Agency, Technology Series Report EPA-660/2-74-052,
June 1974.

Descriptors: Colorado River, *Deep percolation, Irrigation, Irrigation effects, *Irrigation efficiency, Irrigation water, *Return flow, Saline soils, Saline water, Salinity, Water distribution(Applied), Water loss, Water pollution sources, Water quality, *Colorado.

Although the results of this study indicate that existing programs for irrigation scheduling in the Grand Valley to control salinity are having only a marginal effect, the potential for 'scientific' irrigation scheduling has been well established. Also, irrigation scheduling should not be taken individually as a salinity control measure because its effectiveness is not exclusive of the operation of the total irrigation system. Thus, irrigation scheduling is a necessary, but not sufficient, tool for achieving improved irrigation efficiencies. The real strides in reducing the salt pickup resulting from overirrigation will come from the employment of scientific irrigation scheduling in conjunction with improved on-farm irrigation practices. This combined effect could result in a reduction of 300,000 tons annually of salt pickup from the Grand Valley, depending upon the degree of improvement in present on-farm irrigation practices.

74:05G-002
THE LONG-RUN ASYMMETRY OF SUBSIDIES AND TAXES AS ANTIPOLLUTION POLICIES,
Porter, R.C.
Michigan University, Ann Arbor, Department of Economics.
Water Resources Research, Vol. 10, No. 3, p 415-417, June 1974. 1 tab, 11 ref.

Primers on the discharge of unwanted but unpriced effluents into the air and water now treat as commonplace the symmentry between taxes on effluents and subsidies for abatement as means of reducing an industry's pollution. This note shows that on the contrary, serious asymmetry results when entry and exit occur in response to subsidies or taxes. Not only does the quantitative symmetry disappear, but even the qualitative impact (the directions of the effects) of charges and bribes on the volume of firm and industry effluents may differ. More specifically, the possibility emerges than an abatement subsidy offered to an industry may increase the total effluents of that industry.

74:05G-003
DEVELOPMENT OF SALINITY CONTROL TECHNOLOGY IN GRAND VALLEY,
Skogerboe, G.V., Walker, W.R., Bennet, R.S., and Taylor, J.H.
Colorado State University, Fort Collins, Department of Agricultural Engineering.
Presented at the 1974 Annual Meeting of the American Society of Agricultural Engineers, June 23-26, 1974. Stillwater, Oklahoma. 8 fig, 5 ref.

Descriptors: *Saline soils, *Saline water, Salinity, Technology, Irrigation, Agriculture, Colorado, Irrigation operation and management.

Research recently undertaken will evaluate the effects of various irrigation water management practices on the chemical quality of subsurface return flows as well as crop yields. The results of this effort will allow predictions of chemical quality in the Colorado River when various salinity control measures are implemented.

74:05G-004
AGRICULTURAL WASTE MANAGEMENT
Committee on Agricultural Waste Management of the Environmental Engineering Division.
Journal of the Environmental Engineering Division, Vol. 100, No. EE1, p. 1-6, February, 1974. 1 fig.
(See 74:04A-011)

## Section XXI

## WATER RESOURCES PLANNING

### TECHNIQUES OF PLANNING (Group 06A)

74:06A-001
APPLICATION OF SEASONAL PARAMETRIC LINEAR STOCHASTIC MODELS TO MONTHLY FLOW DATA,
McKerchar, A.I. and Delleur, J.W.
Purdue University, Lafayette, Indiana, School of Civil Engineering.
Water Resources Research, Vol. 10, No. 2, p 246-255, April 1974. 6 fig, 2 tab, 16 ref.

Descriptors: *Hydrologic aspects, *Flow data, *Model studies, Forecasting, Mathematical studies, *Seasonal, Hydrologic data, Logarithms.

Stochastic linear models are fitted to hydrologic data for two main reasons: to enable forecasts of the data one or more time periods ahead and to enable the generation of sequences of synthetic data. Short sequences of data lead to uncertainties in the estimation of model parameters and to doubts about the appropriateness of particular time series models. A premium is placed on models that are economical in terms of the number of parameters required. One such family of models is multiplicative seasonal autoregressive integrated moving average (Arima) models. Illustrated is the process of identifying the particular member of the family that fits logarithms of monthly flows, estimating the parameters, and checking the fit. The seasonal Arima model accounts for the seasonal variability in the monthly means but not the seasonal variability of the monthly standard deviations: for this reason its value is limited. The forecasting of flows one or more months ahead is described with an example.

74:06A-002
IMPROVED DYNAMIC PROGRAMMING PROCEDURES AND THEIR PRACTICAL APPLICATION TO WATER RESOURCE SYSTEMS,
Mawer, P.A. and Thorn, D.
Water Research Association, Marlow, England.
Water Resources Research, Vol. 10, No. 2, p 183-190, April 1974. 9 fig, 2 tab, 10 ref.

Descriptors: Water resources development, *Dynamic programming, *Simulation analysis, *Reservoirs, *Long-term planning, *Operation, Optimization, Algorithms, Probability, Markov processes, Reliability, Water demand, Water supply, Pumping plants, Inflow, Rivers, Decision making, Operations research, Mathematical models.

An optimization algorithm is described that uses value iteration dynamic programming and simulation in conjunction with penalty costs to derive long-term operating policies for water resource systems. Feedback from the simulation to the dynamic programming is achieved by means of the penalty costs, which may be interpreted as Lagrangian multipliers. Highly efficient value iteration procedures are developed for two types of problems illustrated by numerical examples: (1) deterministic transition costs--an on-channel reservoir is to be operated in conjunction with a high cost source; and (2) probability transition costs--herein considers the supply of water to a pumped storage reservoir used for amenity purposes and direct regulated water demands. Both problems require finding an operating policy that minimizes long-term running costs and satisfies a reliability objective; the latter problem requires also fulfilling an amenity objective. An indication is given of how the methods described can be applied to multireservoir systems by using the concept of an equivalent reservoir. It is shown that simplified dynamic programming procedures can be formulated by recognizing the inherent nature of the problem and neglecting such things as the serial correlation of reservoir inputs. These procedures produce substantial savings in computation, enabling a much more thorough appraisal of problems than was hitherto possible. Although slightly suboptimal operating policies are obtained, the practical benefits obtained from the general optimization algorithm outweigh most theoretical objections.

74:06A-003
MULTIPLE-OBJECTIVE OPTIMIZATION IN WATER RESOURCE SYSTEMS,
Vemuri, V.
Purdue University, Lafayette, Indiana, Department of Electrical Engineering.
Water Resources Research, Vol. 10, No. 1, p 44-48, February 1974. 2 fig, 1 tab, 8 ref.

Descriptors: Water resources, *Planning, *Management, *Optimization, *Methodology, Equations, Reservoir storage, Reservoir releases, Mathematical models, Systems analysis.

Multiple-objective optimization problems arise naturally in resource management projects. A chief difficulty with multiple-objective optimization is that it is no longer clear what one means by an optimal solution. A possible remedy to this situation is to refine the concept of 'optimal solution' by introducing the so-called 'noninferior solution set.' Then optimization, in a multiple-objective context, boils down to determining the set of noninferior solutions. Determination of the noninferior set is facilitated by relating it, in a one-to-one manner, to a family of auxiliary scalar optimization problems. For a certain class of problems the entire noninferior set can be obtained by solving the auxiliary scalar problem. This procedure is illustrated, considering the problem of determining the optimum storage capacity of a reservoir subject to a specified set of release rules. For demonstration purposes, some simplifications are made. The applicability of this method is presently restricted to the use of a particular functional form for each vector index and no constraints. Further research is needed to extend this method to more general forms of performance indices and to problems in which decision and state variable constraints are present.

74:06A-004
A CRITICAL REVIEW OF VOLLENWEIDER'S NUTRIENT BUDGET MODEL AND OTHER RELATED MODELS,
Dillon, P.J.
Ministry of the Environment, Ontario, Canada, Limnology and Toxcity Branch.
Water Resources Bulletin, Vol. 10, No. 5, p 969-989, October, 1974. 2 tab, 13 ref.

Descriptors: Nutrients, Phosphorus, Eutrophication, Model studies, Water management.

Early attempts at nutrient budget modeling considered only the case where there was no loss of the material by sedimentation, i.e. the substance was assumed to be conservative. Nonstratified and stratified conditions have both been investigated under these terms. An elegant model, taking into account loss of a substance by sedimentation as well as flushing was presented by Vollenweider in 1969. Although this model has several shortcomings, it is particularly valuable because it can have immediate practical value in terms of water management policy development. These basic shortcomings in the model are analyzed and suggestions are made to alter the model to take these factors into account.

74:06A-005
OPTIMAL ALLOCATION OF WATER QUALITY CONTROLS IN URBANIZING RIVER BASINS,
Walker, W.R., Skogerboe, G.V., and Huntzinger, T.L.
Colorado State University, Ft. Collins, Department of Agricultural Engineering.
Water Resources Bulletin, Vol. 10, No. 5, p 845-859, October, 1974. 8 fig,
16 ref.

Descriptors: *Irrigation water, *Municipal water, *Optimization, Salinity, Water quality control, Waste water treatment, Water quality standards.

Urbanizing river basins in the west are encountering serious water quality degradation resulting from the expanded water utilization. In order to avoid aggravating such conditions, water quality controls need to be implemented. The important questions are, therefore, where and how to impose such constraints on the urban and agricultural sectors to achieve the desired level of pollution control. An application of the model developed to address such questions is made in the Utah Lake drainage area of Central Utah as a test of the model's utility. The region is subdivided into five major sub-basins containing both municipal and agricultural water demands. A submodel of each sub-basin is developed which optimizes the water quality control strategies by linking the urban to the agricultural uses and then evaluating the levels of control for each sector. From these results, a cost-effectiveness function for each sub-basin is generated. By jointly considering the cost-effectiveness relationship for each sub-basin, an optimum policy for the entire basin is determined.

74:06A-006
USER-ORIENTED RESEARCH DESIGNS,
Viessman, W., Jr. and Stork, K.E.
Nebraska University, Lincoln, Nebraska Water Resources Research Institute.
Water Resources Bulletin, Vol. 10, No. 3, p 440-446, June, 1974.

Descriptors: *Research and development, *Research priorities, *Technology, *Project planning, *Project purposes.

A user-oriented research plan is presented herein. Its principal components are: (1) a mechanism for identifying social goals and priorities; (3) a program planning technique for designing projects to impact on important research objectives; (4) a mechanism for coordinating research activities of important research producers; (5) a structure for encouraging and establishing interdisciplinary team efforts when they are required; (6) a well-coordinated technology transfer plan; and (7) an effective method for promoting and sustaining user-researcher cooperation. Both basic and applied research designs are examined and criteria presented. The implementation of research plans is also discussed and various factors which play a role in implementation are outlined including: coordination, goal interpretation and priority setting, project planning, project review, interdisciplinary considerations and the user-researcher interface.

74:06A-007
INTERDISCIPLINARY MODELING IN THE ANALYSIS OF THE SALINITY PROBLEMS OF THE SAFFORD VALLEY,
Muller, A.B.
Arizona University, Tucson, Department of Hydrology and Water Resources.
Water Resources Bulletin, Vol. 10, No. 2, p 245-]55, April, 1974. 6 fig, 9 ref.

Descriptors: Salinity, Saline water, Saline soil, Model studies, Groundwater, Groundwater recharge, Leaching, Cotton, Economics.

A groundwater quality change of +0.13 millimhos electrical conductivity was documented between 1940 and 1972 in the Safford Valley. The change is attributable to four principal mechanisms: pumping-encouraged saline artesian aquifer leakage, natural recharge of the water table aquifer by saline waters, leaching of agricultural waters into the aquifer and the lateral flow of groundwater through saline lacustrine beds. A hydrologic study of the area has shown the first of these mechanisms to be predominant. Salinity modeling has shown three regions of salinity change, and salinity increase projections for each are determined. An economic analysis and an economic model are then combined with the physical model, yielding information as to when certain economic conditions are reached with respect to the salinity increase.

74:06A-008
SIMULATION TECHNIQUES FOR WATER PROJECT ANALYSIS,
Holloway, M.L. and Tischler, L.F.
Office of the Governor of Texas, Austin, Office of Information Services.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 100, No. IR3, p 211-229, September, 1974. 6 fig, 4 ref, 2 append.

Descriptors: *Simulation analysis, Project planning, Projects, Analytical techniques, Water supply development.

This paper describes a set of analytical tools designed to measure market and nonmarket benefits and costs of large water resource systems; selected components may be useful for analyzing individual small projects or a general application to a system of small projects. The focus of the paper is on two major aspects: (1) A description of techniques developed at the Texas Water Development Board to measure economic, environmental, and social impacts of water development projects; and (2) the possible application of these techniques to single small projects or to a system of small projects within a larger hydrologic, environmental, social, and economic system.

74:06A-009
WATER MANAGEMENT THROUGH IRRIGATION AND DRAINAGE: PROGRESS, PROBLEMS, AND OPPORTUNITIES,
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 100, No. IR2, p 153-178, June, 1974. 28 ref.

Descriptors: *Water management (applied), Water conservation, Water quality, Social needs, Social impact.

The purpose of the current effort by the Irrigation and Drainage Research Committee is not to make yet another recommendation, but rather to encourage civil engineers to reflect on the problem at hand so that they can draw their own conclusions and, as appropriate, initiate whatever action they wish.

74:06A-010
MODELING THE HYDROLOGIC EFFECTS RESULTING FROM LAND MODIFICATION,
Fogel, M.M., Duckstein, L., and Kisiel, C.C.
Arizona University, Tucson, Watershed Management Department.
Transactions of the American Society of Agricultural Engineers, Vol. 17, No. 6, p 1006-1010, November-December, 1974. 3 fig, 1 tab, 22 ref.

Descriptors: *Model studies, Land forming, Hydrology, Watershed management, Watersheds (basins), Sediments, Sediment yield, Runoff.

The basic objective of this paper is to present a methodology that can predict the long-term hydrologic effects of land modifications on ungaged watersheds. As used here, "to predict" is used interchangeably with "to forecast" in the hydrologic sense. The essential components of the procedure are an event-based stochastic model of precipitation as input into a deterministic watershed model that transforms the inputs into such desired hydrologic variables as water yield, peak runoff rate and sediment yield.

## Section XXII

## WATER RESOURCES PLANNING

## EVALUATION PROCESS (Group 06B)

74:06B-001
**APPRAISAL OF IRRIGATION PROJECTS AND RELATED POLICIES AND INVESTMENTS,**
**Bassoco, L.M., Norton, R.D., and Silos, J.S.**
Ministry of the Presidency, Mexico 1, D.F., Mexico
Water Resources Research, Vol. 10, No. 6, p 1071-1079, December 1974.
2 fig, 4 tab, 14 ref.

Descriptors: *Project post evaluation, Project benefits, Linear programming, Irrigation districts, Irrigation programs, Irrigation.

Seven examples of analysis with linear programming models are used to illustrate methods of treating interdependence in the appraisal of irrigation projects. The kinds of interdependence analyzed are (1) between investment projects and other policy instruments, (2) among different types of investment projects, and (3) between local and sector-level decision on investment outlays. The applications discussed refer to irrigation districts in the central plateau and northwestern littoral of Mexico

# Section XXIII

## WATER RESOURCES PLANNING

### COST ALLOCATION, COST SHARING, PRICING/REPAYMENT (Group 06C)

74:06C-001
DETERMINATION OF THE OPERATION AND MAINTENANCE COSTS OF IRRIGATION PROJECTS,
Rydzewski, J.R.
Southampton University, United Kingdom.
International Commission on Irrigation and Drainage, p 9-13, January 1974.
Append.

Descriptors: *Irrigation programs, *Irrigation, *Irrigation operation and maintenance, Project planning, Projects, Cost analysis.

The paper reviews the problems which stem from an inadequate knowledge of the nature and extent of recurrent expenses on irrigation projects. It then presents a methodology for collecting such information from the field and discusses the reasoning behind it. Finally, it appeals to project administrators for cooperation with this type of survey, the results of which could have a beneficial influence on policies affecting project management.

74:06C-002
PRICING IRRIGATION WATER IN IRAN,
Gardner, B.D., Madhi, Y., Partovi, S., Morteza, H., and Mehdi, S.
Utah State University, Logan, Department of Economics.
Water Resources Research, Vol. 10, No. 6, p 1080-1084, December 1974. 2 fig, 1 ref.

Descriptors: *Irrigation water, *Water costs, Irrigation, Irrigation districts, Costs, Cost analysis.

Iran has nationalized water and is faced with the problems of pricing it. A proposal for pricing irrigation water is presented in which water is managed by nonprofit water authorities. An irrigation project is divided into zones, and a single price is proposed for each zone. Operation and maintenance costs are set as a lower limit on price, and a certain fraction of ability to pay is set as an upper limit. Zones are ranked by assigned reimbursable costs, and a system is proposed that would produce water revenues in aggregate equal to total project reimbursable costs. For those zones where water is priced above reimbursable cost the price is set at that level where the price minus reimbursable costs, as a percentage of the difference between the upper limit and reimbursable cost, is the same for all zones. For those zones where the price is below reimbursable cost, the recommended price is at the upper limit.

74:06C-003
EFFECT OF NITRATE AND SEDIMENT CONSTRAINTS ON ECONOMICALLY OPTIMAL CROP PRODUCTION,
Onishi, H. and Swanson, E.R.
Illinois University, Urbana-Champaign, Department of Agricultural Economics.
Journal of Environmental Quality, Vol. 3, No. 3, p 234-238, July-September, 1974. 2 fig, 1 tab, 12 ref.

Descriptors: *Watershed management, *Linear programming, Nitrogen, Nitrates, Conservation, Water quality, Reservoirs, Erosion.

Crop systems and practices which are economically optimal in a 485.6-ha (1,200-acre) watershed with a planned recreational reservoir were determined under conditions of varying constraints on water quality in the reservoir. The technique of linear programming was used. Two requirements related to sedimentation and three requirements related to nitrate concentration in the leachate below the root zone were considered. Thus, six combinations of restrictions on the choice of optimal crop systems were imposed. A system of charges for all sediment introduced into the reservoir substantially reduced erosion, irrespective of the limit placed on nitrate concentration in the leachate below the root zone. Relaxation of the nitrate limit from 10 mg/liter to no limit approximately doubled the net income above nonland costs.

## Section XXIV

# WATER RESOURCES PLANNING

## WATER DEMAND (Group 06D)

74:06D-001
MODELING EVAPOTRANSPIRATION AND SOIL MOISTURE,
Saxton, K.E., Johnson, H.P., and Shaw, R.H.
United States Department of Agriculture, Agricultural Research Service,
Columbia, Missouri.
Transactions of the American Society of Agricultural Engineers, Vol. 17, No. 4,
p 673-677, July-August 1974. 7 fig, 2 tab, 17 ref.

Descriptors: *Computer models, *Model studies, *Soil moisture, *Evapotranspiration, Evaporation, Moisture tension, Moisture content, Corn, Bromegrass, Hydrologic data, Hydrologic systems, Agriculture.

A digital model was presented which was developed to compute daily actual ET and soil moisture profiles from inputs of daily potential ET and crop and soil moisture characteristics. Interception evaporation, soil evaporation, and plant transpiration were computed separately by several relationships; then these values were combined to provide daily actual ET estimates. Soil moisture was redistributed by tension-conductivity relationships. The model was calibrated and verified by 3 years of data from March through November from two research watersheds, one in corn and the other in bromegrass. The calculated actual ET amounts and soil moisture profiles agreed sufficiently with observed data to be quite useful for hydrologic research and models.

74:06D-002
ESTIMATION OF POTENTIAL AND CROP EVAPOTRANSPIRATION,
Hargreaves, G.H.
Utah State University, Logan, Agricultural and Irrigation Engineering Department.
Transactions of the American Society of Agricultural Engineers, Vol. 17, No. 4,
p 701-704, July-August 1974. 2 tab, 13 ref.

Descriptors: *Evapotranspiration, Evaporation pan, Evaporation, Temperature, Lysimeter, Agriculture, Scheduling, Climatic data.

This paper analyzes the relative importance of weather elements on potential evapotranspiration and presents a methodology requiring a minimum of data, providing for simplicity of computation and presenting a good fit of lysimeter evapotranspiration measurements for a wide range of climatic conditions. Grass evapotranspiration or potential evapotranspiration can be approximated from a variety of equations. The most frequently used elements for computation include mean air temperature and some form of radiation and/or day length. Other elements are of relatively minor importance in low elevation arid locations. For these locations the simple equation (PET = MF x T), requiring only temperature measurements produces satisfactory results. In humid areas a correction for relative humidity is added.

74:06D-003
EFFECTS OF AGRICULTURAL ACREAGE REDUCTION ON WATER AVAILABILITY AND SALINITY IN THE UPPER COLORADO RIVER BASIN,
Howe, C.W. and Orr, D.V.
Colorado University, Boulder, Department of Economics.
Water Resources Research, Vol. 10, No. 5, p 893-897, October, 1974. 2 fig, 4 tab, 8 ref.

Descriptors: Salinity, Saline water, Colorado River, Colorado River basin, Cost analysis, Costs, Water demand, Water management, Water quality, Water supply, Water transfer.

Consideration is given to the costs in terms of regional income likely to be lost if irrigated acreages were to be reduced in the Upper Main Stem subbasin of the Colorado River as a means of freeing water for alternative uses and reducing salt loadings. The cost estimates, known to be biased upward, appear competitive with other water augmentation and salinity reduction programs.

## Section XXV

## WATER RESOURCES PLANNING

### WATER LAW AND INSTITUTIONS (Group 06E)

74:06E-001
ON THE MEASUREMENT OF ENVIRONMENTAL IMPACTS OF PUBLIC PROJECTS FROM A SOCIOLOGICAL PERSPECTIVE,
Singh, R.N. and Wilkinson, K.P.
East Texas State University, Commerce, Department of Sociology and Anthropology.
Water Resources Bulletin, Vol. 10, No. 3, p 415-424, June, 1974. 1 fig, 2 tab, 45 ref.

Descriptors: *Environment, *Environmental control, Attitudes, Social impact, Watershed management, Watersheds (Basins)

The major objectives are: (1) to identify the problems involved in measuring the environmental impacts of public projects from selected perspectives, and (2) to elaborate a sociological approach used in an empirical investigation in that respect. The construct of environmental impact of a planned action is generally operationalized from different perspectives and with different methodological emphases in the various disciplines. Even the term environment does not elicit agreement among users as to its exact meaning. Although there has been a steady increase in the number of studies from a sociological perspective concerning environmental problems, there is lack of sociological counsel in writing environmental impact statements. Overall, we lack sociological methodology and operational procedures for that purpose. In an attempt to bring some empirical focus to this field, attitudinal measures employed to discover how residents of a river basin perceived negative and positive environmental impacts of a proposed watershed development project are reviewed.

## Section XXVI

## WATER RESOURCES PLANNING

## ECOLOGIC IMPACT OF WATER DEVELOPMENT (Group 06G)

74:06G-001
PROBLEMS OF SCALE AND DETAIL IN ECOLOGICAL MODELING,
Goodall, D.W.
Utah State University, Logan, Ecology Center.
Journal of Environmental Management, Vol. 2, No. 2, p 149-157, April 1974.
1 ref.

Descriptors: *Model studies, *Ecosystems, Dynamics.

The importance of niche structure in ecosystem dynamics is emphasized. This implies that an ecosystem model which ignores species differences runs the risk of neglecting important elements in its dynamics. Unless circumstances permit direct comparison of a simplified model with the observed behaviour of a representative range of ecosystems, it is recommended that acceptance of the simplified model be based on a demonstration that deviations from the behaviour of an alternative model taking biological diversity fully into account are negligible for the purposes in question. Spatial heterogeneity, like biological diversity, may contribute greatly to the dynamics of an ecosystem, and a simplified model which ignores it should be accepted only if justified either by an empirical test or by a comparison with a more complex model taking the heterogeneity into account.

## WATER RESOURCES

### DATA ACQUISITION (Group 07B)

74:07B-001
SOIL TEMPERATURE MODELING USING AIR TEMPERATURE AS A DRIVING MECHANISM,
Hasfurther, V.R. and Burman, R.D.
Wyoming University, Laramie, Civil Engineering Department.
Transactions of the American Society of Agricultural Engineers, Vol. 17, No. 1, p 78-81, January-February 1974. 6 fig, 1 tab, 1 append.

Descriptors: *Model studies, *Mathematical models, *Soil temperature, *Air temperature, Temperature, Climatic data, Agriculture.

A mathematical model for predicting soil temperature from air temperature is developed and should have a great utility because of the availability and economy of air temperature measurements as compared to soil temperature measurements. The mathematical model will predict daily average soil temperatures within approximately three degrees farenheit at depths of from 1 inch to 72 inches based on past measurements of average daily air temperature as reported by a standard weather bureau shelter. Prediction of future soil temperatures is largely limited by the accurate prediction of air temperatures in advance. The results of the mathematical modeling technique show that the deviations of predicted values from the actual values (smoothed values) were usually within three degrees and more often than not were less than three degrees in error.

74:07B-002
REMOTE SENSING TECHNIQUES FOR EVALUATION OF SOIL WATER CONDITIONS,
Schmer, F.A. and Werner, H.D.
South Dakota State University, Brookings, Remote Sensing Institute.
Transactions of the American Society of Agricultural Engineers, Vol. 17, No. 2, p 310-314, March-April 1974. 6 fig, 3 tab, 8 ref.

Descriptors: *Remote sensing, *Soil moilture, *Grain Sorghum, Films, Filters, Infrared radiation, Wavelength, Reflectance, Irrigation, Agriculture, Irrigation practices.

The results of two years of soil water research indicate that remote sensing did provide a valuable tool in evaluation of soil water condition for the crop and soils studied. Multispectral data collection and analysis seem to hold the key to the development of the necessary remote sensing techniques for operational use. Results indicate that early season soil water conditions with little crop cover of the soil were best monitored with the blue spectral band. As the season progressed and the crop canopy developed, the sorghum became an indicator of the available soil water; and the green and red spectral bands became more useful with red the best of all. Adjusting the film densities from the reflected imagery to account for variations in incoming radiation provided improved results in several cases. Thermal infrared radiation may possibly be the most valuable tool for widespread soil water evaluation since it seems less affected by differences in vegetative and soil surfaces.

74:07B-003
CONTROLLING CENTER PIVOT SPRINKLERS FOR EXPERIMENTAL WATER APPLICATION,
Heerman, D.F.
United States Department of Agriculture, Agricultural Research Service, Fort

Collins, Colorado.
Presented at 1974 Winter Meeting of the American Society of Agricultural Engineers, December 10-13, 1974. Chicago, Illinois. 7 fig, 7 tab.

Descriptors: *Sprinkler irrigation, *Research equipment, Data collections, Application equipment, Application methods, Irrigation methods, Irrigation practices, Irrigation.

Irrigation systems and techniques are often required for various water treatments for water management research. Center pivot irrigation systems were successfully modified to vary water application depths on droplet size on small plots or entire sectors. The modifications included controls for varying travel speed and for automatically starting and stopping individual sprinkler heads. The modifications made on center pivot systems for three different experiments were successfully used for applying water treatments. When systems were run at constant rotation speeds, the coefficient of variability was generally less than 20%. Water treatments applied with center pivot systems required minimal labor since the systems were designed to automatically affect the desired treatments as the systems passed over the plot areas.

74:07B-004
SAMPLING AND CALCULATION METHODS FOR DETERMINING QUANTITIES OF NITROGEN AND PHOSPHORUS IN WATERSHED RUNOFF,
Burwell, R.E., Schuman, G.E., Piest, R.F., Larson, W.E., and Alberts, E.E.
Presented at 1974 Winter Meeting of the American Society of Agricultural Engineers, December 10-13, 1974. Chicago, Illinois. 2 fig, 5 tab, 10 ref.

Descriptors: Nitrogen,, *Phosphorus, *Agricultural runoff, Sediments, Watersheds (Basins), Sampling.

The nitrogen and phosphorus content of surface runoff from two watersheds in southwestern Iowa was analyzed for a 5-year period (1969-1973). Sampling and calculation procedures were evaluated for quantifying discharges of water-soluable NO3-N, NH4-N, and inorganic P and sediment-associated Kjeldahl N and NaHCO3-extractable P. The arithmetic mean nutrient concentration of samples collected during major runoff (greater than 10 cfs), multiplied by the quantity of water or sediment discharged, compared favorably with a standard integration procedure for determining N and P discharge associated with surface runoff.

74:07B-005
SAMPLING TOOL FOR TAKING UNDISTURBED SOIL CORES,
Robertsom, W.K., Pope, P.E., and Tomlinson, R.T.
Florida University, Gainesville.

Soil Science Society of America Proceedings, Vol. 38, No. 5, p 855-857, September-October, 1974. 4 fig, 2 ref.

Descriptors: Sampling, Soil investigations, Soil properties, Soil surveys, Soil tests, Leaching.

A tool is described that can be attached to a commercially available soil sampler that will take undisturbed soil cores 15 cm in diameter and 75 cm long in corlon tubes. The tubes were sealed at the bottom with a sheet of plastic in which drainage tubes were inserted. Leaching studies could be made when tubes containing cores were placed on racks in the greenhouse. Further refinements include suction cups at regular intervals in the side of the column for nutrient movement studies and porous plates at the top and/or the bottom to make moisture tension in the profile similar to natural conditions.

74:07B-006
A METHOD FOR MEASURING FIRST-STAGE SOIL WATER EVAPORATION IN THE FIELD,
Arkin, G.F., Ritchie, J.T., and Adams, J.E.
Texas Agricultural Experiment Station.
Soil Science Society of America Proceedings, Vol. 38, No. 6, 951-954,
November-December, 1974. 5 fig, 8 ref.

Descriptors: Evaporation, Soil water, Soil water movement, Automation, Mulching, Soil investigations, Evapotranspiration, Measurement.

An economical, automated method was developed for measuring soil water evaporation during first-stage drying simultaneously at several locations in a field to evaluate the effectiveness of mulches and crop canopies in reducing soil water evaporation. The method also provides a reasonable procedure for separating soil water evaporation during first-stage drying from transpiration, when the total evapotranspiration rate is accurately measured. Water flow through a thin evaporation plate with a known surface area is measured and used as a direct indicator of the evaporation rate. Flow rates can be recorded manually or automatically. Field tests of evaporation indicated that the resolution of the system was equal to that of a precision weighing lysimeter and that the system gave reasonable accuracy on an hourly basis. Mulch rates of 19000, 4,000 and 10,000 kg/ha-1 reduced daily soil water evaporation measured with this method by 26, 59, and 78% of the bare soil evaporation. Cumulative daily soil water evaporation was reduced by 57 and 71% under plant canopies with 100- and 50-cm row spacings ans similar leaf area indices (3.0 and 2.7, respectively).

74:07B-007
AN AUTOMATIC PUMPING SAMPLER FOR EVALUATING THE TRANSPORT OF PESTICIDES IN SUSPENDED SEDIMENT,
Parr, J.F., Willis, G.H., McDowell, L.L., Murphree, C.E., and Smith, S.
Journal of Environmental Quality, Vol. 3, No. 3, p 292-294, July-September,
1974. 1 fig, 3 tab, 7 ref.

Descriptors: *Pesticides, *Sampling, Sediment, Suspended solids, Laboratory tests, Equipment, Water quality, Water pollution.

Laboratory tests were conducted to evaluate the utility of an automatic pumping sampler for assessing the transport and concentration of pesticides in suspended sediment. Pesticide-sediment-water mixtures were formulated with pesticide-sediment ratios ranging from 1:15,000 to 1:500. After stirring periods of 10 and 60 min, these formulations were pumped through the sampler and aliquots collected for pesticide analysis. Recovery of DDT, trifluralin, toxaphene, and mirex exceeded 90%, based on their concentrations immediately prior to pumping. Adsorption of pesticides to the various plastic, rubber, and fiberglass sampler components was minimized by the high flow velocity and rapid delivery systems ehich ensured a short time of contact (seconds) between the sample and internal surfaces. These tests indicate that the sampler is suitable for use in evaluating the transport of relatively water-insoluble pesticides in suspended sediment.

74:07B-008
EVALUATION OF SURFACE WATER RESOURCES FROM MACHINE PROCESSING OF ERTS MULTISPECTRAL DATA,
Mausel, P.W., Todd, W.J., Baumgardner, M.F., Mitchell, R.A., and Cook, J.P.
Indiana State University, Terre Haute.
Journal of Environmental Quality, Vol. 3, No. 4, p 316-321, October-December,
1974. 5 fig, 1 tab.

Descriptors: *Water pollution control, *Water pollution, Water management, Water quality, Water quality control, Environmental control, Monitoring, Hydrology.

Water resource data that are useful to environmental scientists and planners frequently are missing, incomplete, or obtained irregularily. A new source of surface hydrological information can be obtained as often as every 18 days in some areas through machine-processing of Earth Resources Techonology Satellite (ERTS) multispectral scanner data. This research focused on the surface water resources of a large metropolitan area, Marion County (Indianapolis), Indiana, in order to assess the potential value of ERTS spectral analysis to water resources problems. The results of the research indicate that all surface water bodies over 0.5 ha were identified accurately from ERTS multispectral analysis. Five distinct classes of water were identified and correlated with parameters which included the i) degree of water siltiness; ii) depth of water; iii) presence of macro and micro biotic forms in the water; and iv) presence of various chemical concentrations in the water.

# Section XXVIII

## RESOURCES DATA

## EVALUATION, PROCESSING AND PUBLICATION (Group 07C)

74:07C-001
A NOTE ON THE USE OF SPECTRAL ANALYSIS TO DETECT LEADS AND LAGS IN ANNUAL CYCLES OF WATER QUALITY,
Dowling, J.M.
Colorado University, Boulder, Department of Economics.
Water Resources Research, Vol. 10, No. 2, p 343-344, April 1974. 1 tab, 4 ref.

Descriptors: *Time series analysis, *Water quality, Statistics, Statistical methods, *Input-output analysis.

Spectral analytic phase statistics can be interpreted as absolute delays in physical time only if the two series are related as input and output by a simple delay process. For all other linear input-output systems it is incorrect to interpret phase as if there is a simple delay between input and output series. To clarify interpretation of phase leads and lags, an explicit model should be constructed in the time domain. Without such clarification, ambiguities will be present in the interpretation of phase statistics.

74:07C-002
PARAMETER IDENTIFICATION IN FIELD PROBLEMS,
Simundich, T.M.
California University, Santa Barbara, Department of Mechanical Engineering.
Water Resources Research, Vol. 10, No. 1, p 73-79, February 1974. 1 fig, 6 tab, 23 ref.

Descriptors: *Data collections, *Hydrologic data, *Systems analysis, *Parametric hydrology, Mathematical models, Optimization.

In water resources field problems, unknown physical parameters in the governing partial differential equations must be determined before relevant numerical results can be obtained. The identification of these parameters is formulated as a minimization problem in which the function to be minimized is a least squares comparison between the model equation and the systems responses (the field data). The minimization technique utilized is the Fletcher-Powell method. Three typical water resources field problems are used as examples to demonstrate the technique.

74:07C-003
MULTIVARIATE TECHNIQUES FOR WATER QUALITY ANALYSIS,
Mahlock, J.L.
Mississippi State University, State College, Department of Civil Engineering.
Journal of the Environmental Engineering Division, American Society of Civil Engineers, Vol. 100, No. EE5, Proceedings paper No. 10840, p 1119-1132, October 1974. 9 tab, 5 equ, 8 ref.

Descriptors: *Environmental engineering, *Water quality control, *Statistical methods, Regression analysis, Estimating, Data collections, Methodology, Information retrieval, Systems analysis, Equations.

The application of multivariate statistical techniques to analysis of water quality data is demonstrated. Study results indicate that a simultaneous, multiple regression technique may be used for supplying missing observations and that at any particular level the entire data matrix may be considered, thus reducing the computational effort. Multivariate technique applications herein center on either extracting information from the data or testing hypotheses which may arise concerning the data. The techniques considered include principal components, canonical correlation, partial correlation, multivariate analysis of variance (MANOVA), and discriminant analysis. Examples are presented demonstrating the application of these methods.

# Section XXIX

## ENGINEERING WORKS

### STRUCTURES (Group 08A)

74:08A-001
DETERIORATION OF CONCRETE DITCH LINERS IN SALINE-ALKALI SOIL,
Grass, L.B. and Koluvek, P.
Imperial Valley Conservation Research Center, Brawley, California, Agricultural Research Service.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 100, No. IR4, p 477-484, December, 1974. 3 fig, 2 tab, 10 ref.

Descriptors: Concrete construction, Concrete structures, Concrete-lined canals, Irrigation canals, Irrigation engineering.

Deterioration of portland cement concrete ditch liners in Imperial Valley, California, is first indicated by a softening, cracking, and eroding of the liner, beginning at the top and progressing downward. Deterioration is most severe on the north slope of east-west oriented ditches. Both chemical and physical reactions are responsible for the gradual softening of the concrete ditch liners. Physical forces cause weakened liners to crack, which accelerates the chemical attack by exposing new surfaces. Since Ca and other elements are more soluble in deteriorated concrete at the upper portions of the liner than in the lower portions, chemical deterioration seems the predominant form of deterioration. External physical forces, e.g., cracking due to differences in temperature above and below the water levels, accelerate the chemical corrosion.

74:08A-002
DESIGNING TRICKLE IRRIGATION LATERALS FOR UNIFORMITY,
Howell, T.A. and Hiler, E.A.
Texas A&M University, College Station, Department of Agricultural Engineering.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 100, No. IR4, p 443-454, December, 1974. 9 fig, 11 ref, 2 append.

Descriptors: Irrigation design, Irrigation engineering, Irrigation systems, Hydraulic design, Uniform flow,

Design equations are presented that allow the length of a trickle irrigation lateral to be designed to meet specific uniformity criteria. The emitter flow function is utilized to determine the allowable pressure loss to meet the uniformity standards. The emitter flow variation of the lateral (increase or decrease as compared to the design flow rate) is a function of the uniformity coefficient. Thus, by knowing the emitter flow function, elevation change, and design uniformity, the allowable pipe friction loss can be computed. Then taking the pipe size, pipe roughness coefficient (Hazen-Williams), reduction coefficient for dividing flow, average emitter flow rate, allowable pipe friction loss determined previously, and either the number of emitters per lateral, N, or the average emitter spacing, S, into account the lateral length, L, can be determined. The solution for a given value of uniformity is a log-linear (log N versus log L or log S versue log L) with a slope that depends only on the flow rate exponent in the pipe friction loss equations for level laterals.

74:08A-003
ECONOMIC PIPE SIZING IN PUMPED IRRIGATION SYSTEMS,
Perold, R.P.
Stellenbosch University, Republic of South Africa, Department of Agricultural Engineering.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 100, No. IR4, p 425-441, December, 1974. 7 fig, 1 tab, 11 ref, 2 append.

Descriptors: Irrigation design, Piping systems, Economics, Irrigation engineering.

The method whereby the most economical pipe sizes in a pumped system is found by determining the flow rates at which pipe sizes should be changed from one size to the next, according to the time pumped per year, is developed for general application. Use of the method in the design of branched flow system is examined for both fixed head and variable head pumping plants. The method, as illustrated by an example, is found to be convenient and gives the best solution fairly rapidly.

74:08A-004
MIXING IN SPRINKLER IRRIGATION SYSTEMS,
Hermann, G.J., McMaster, G.M. and Fitzsimmons, D.W.
CH2M/Hill, Redding, California, Agricultural Engineering.
Transactions of the ASAE, Vol. 17, No. 6, p 1020-1024 & 1028, November-December, 1974. 6 fig, 9 ref.

Descriptors: *Sprinkler irrigation, Irrigation practices, Irrigation, Mixing, Irrigation water, Fertilization, Fertilizers.

A study was conducted at Aberdeen, Idaho, to determine the amount of mixing between two fluids traveling in a branching flow lateral under the field conditions found in a sprinkler irrigation system. The objective of the study was to develop methods to predict the effects of state of flow, of couplers and of branching flow on mixing and dilution of chemicals injected into operating sprinkler irrigation laterals. The resulting basic understanding of branching flowmixing could be used to manage chemical applications through sprinkler systems for best placement and effectiveness. Using irrigation systems to apply chemicals will reduce the usage of conventional application equipment and result in labor and energy savings as well as a reduction of soil compaction and crop damage.

74:08A-005
PIPE SIZE SELECTION FOR COMMUNITY IRRIGATION SYSTEMS,
Chu, S.T.
South Dakota State University, Brookings, Department of Agricultural Engineering.
Transactions of the ASAE, Vol. 17, No. 6, p 1029-1032 & 1037, November-December, 1974. 3 fig, 3 tab, 13 ref.

Descriptors: Irrigation design, Irrigation engineering, Irrigation, Pipelines, Pipes, Piping systems, Economics, Community development.

An analytical result and procedures to select optimal pipe sizes for the water delivery pipe network of community irrigation systems were developed. The application of the presented method to the Shamrock Irrigation Project showed that the result is an acceptable approximation of the result obtained by linear programming. The time required to use the presented method for selecting pipe sizes is less than the time needed to prepare computer cards for the linear programming.

74:08A-006
ANALYSIS OF CANAL SEEPAGE TO INTERCEPTOR DRAIN,
Sharma, H.D. and Chawla, A.S.
U.P. Irrigation Research Institute, Roorkee, India.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 100, No. IR3, p 351-369, September, 1974. 11 fig, 5 ref, 2 append.

Descriptors: *Canal seepage, Seepage, Seepage control, Drainage effects, Drainage practices.

An analytical solution is obtained with the help of conformal mapping for the problem of steady seepage from a canal into an interceptor drain and to the main drainage lain in homogeneous and isotropic medium extending to infinite depth. Equations have been given to determine the seepage discharge into the drain and the coordinates of the phreatic surface. The solutions of the equations have been presented in the form of dimensionless curves to facilitate computations. The analysis indicates that discharge to the interceptor drain increases with an increase in the bed width of the channel and diameter of interceptor drain, whereas it decreases with an increase in distance between the canal and the interceptor drain. As the drain is brought closer to the canal, the rate of increase of seepage into the drain increases. The effect of the drain diameter in intercepting seepage discharge is more pronounced at a deeper setting of the drain.

74:08A-007
BASIC PRINCIPLES OF PULSE IRRIGATION,
Karmeli, D. and Peri, G.
Technion Haifa Israel, Faculty of Agricultural Engineering.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 100, No. IR3, p 309-319, September, 1974. 2 fig, 3 tab, append.
(See 74:03F-153)

74:08A-008
CENTER PIVOT DESIGN CAPACITIES IN EASTERN COLORADO,
Heermann, D.F., Shull, H.H. and Mickelson, R.H.
United States Department of Agriculture, Fort Collins, Colorado.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 100, No. IR2, p 127-141, June, 1974. 9 fig, 3 tab, 15 ref.

Descriptors: *Sprinkler irrigation, Irrigation design, Irrigation engineering, Irrigation practices, Irrigation systems, Flow rates, Design flow.

Design system capacities were developed for center pivot sprinklers irrigating corn in the Central Great Plains by simulating irrigations for 60 years of climatic data collected at Akron, Colorado. The system design provides three probability levels of net irrigation requirements versus optimum soil water depletion as affected by soils with various water holding capacities. The design system capacities developed from the simulation model allow for the depletion of available soil water. An emperical procedure for determining the net system capacity from ET (net) as affected by allowable depletion level is presented.

74:08A-009
A LABORATORY TEST OF SOME DRAIN TUBE FILTER MATERIALS,
McKyes, E. and Broughton, R.S.
Macdonald Campus of McGill University, Ste Anne de Bellvue 800, Quebec.
Journal of the Canadian Society of Agricultural Engineering, Vol. 16, No. 2, p 60-62, December 1974. 5 fig, 6 ref.

Descriptors: *Drainage, *Drainage effects, *Drainage engineering, *Drainage practices, Filtration, Drains, Materials testing.

Drainage systems frequently fail in fine sandy soils because of particles entering drain tiles in sufficient quantity to block the drains. Attempts have been made to employ filters outside tiles to allow only soil-free water to enter the system. Filtering materials have included straw, fiberglass sheet, polyester fiber sheet, nylon fiber sheet, coconut fibers, and others. Some field experience has shown that the flow of water can decrease over the years through filters, especially in iron-rich soils. However, no laboratory tests have been performed to note the effect of months of water-flow through filters, and the relative amounts of sand entry through filters over a long period. The purpose of this study was to test some commercially available or promising filters for corrugated plastic drain tubes and to access their effect on water and soil entry into tubes over approximately 2 mo of continuous operation.

74:08A-010
SCREEN THEORY FOR WELLS AND SOIL DRAINPIPES,
Sami Selim, M. and Kirkham, D.
Iowa State University, Ames, Department of Agronomy.
Water Resources Research, Vol. 10, No. 5, p 1019, 1030, October, 1974. 19
fig, 3 tab, 19 ref.

Descriptors: *Well screen, *Wells, Theoretical analysis, Hydraulic design, Hydraulic equipment, Hydraulic properties, Irrigation wells.

A theoretical solution is given for steady flow in a confined aquifer to a well tube having equally distributed screens. It is shown, quantitatively, by use of Darcy's law and Laplace's equation, that more flow results if a given total length of well screen is utilized in a number of sections over the full length of the well tube than if the given length of well screen is all used at the bottom of the tube. For a pumped well of 0.25-ft radius, 200-ft radius of influence, 50-ft thickness of aquifer, and 25-ft length of screen the use of the screen in five 5-ft long sections equally distributed over the well tube results in 25% more well flow than if the 25-ft length of screen is all in one piece at the lower 25 ft of the aquifer. The results are presented in tables and graphs having dimensionless parameters so that the flow for a particular flow system may be found in any units. Mathematically, the problem is of the mixed boundary value type.

## Section XXX

## ENGINEERING WORKS

## HYDRAULICS (Group 08B)

74:08B-001
HYDRODYNAMICS OF SURFACE IRRIGATION-ADVANCE PHASE,
Sakkas, J.G. and Strelkoff, T.
California University, Davis, Department of Water Science and Civil Engineering.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 100, No. IR1, Paper 10422, p 31-48, March 1974, 8 fig, 19 ref, append.

Descriptors: *Seepage, *Open channel flow, *Furrow irrigation, *Surface irrigation, Numerical analysis, Infiltration, Hydrodynamics.

The Saint-Venant equations governing gradually varied, unsteady flow in an open channel with seepage may be put into characteristic form and solved numerically in finite steps along the irregular network formed by the characteristic lines using a simple predictor-corrector scheme. Infiltration into the soil is assumed to depend solely upon contact time between water and soil. In regions of substantial curvature of the characteristic lines, step size is reduced to preserve accuracy. Near the very front of the advancing stream, where the forward and backward characteristics curve extremely sharply and merge with their envelope, the wave-front trajectory, the numerical approximations to the characteristic equations break down and are replaced by the assumption that water velocity is independent of the distance coordinate and equals front-propagation speed.

74:08B-002
DISCHARGE AND TRAVEL TIME FOR GROUND-WATER CONDUITS,
Butler, S.S. and Gundlach, D.L.
University of Southern California, Los Angeles, Department of Civil Engineering.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 100, No. IR1, Paper 10393, p 17-29, March 1974. 11 fig, 1 tab, 4 ref, append.

Descriptors: *Groundwater movement, *Discharge(Water), *Travel time, Mathematical models, Aquifers, Water yield, Permeability, Porous media, Irrigation water, Percolation, *Conduits.

A system of mathematical and graphical procedures gives solution for the steady-flow discharge and travel time for nonuniform confined groundwater conduits in which any or all of the following characteristics vary from point to point: permeability, porosity, and cross-sectional area. The methods based on the Darcy equation and the equation of continuity. Modified procedures give relatively simple solutions with some loss in accuracy.

74:08B-003
PROCEEDINGS OF THE SECOND INTERNATIONAL DRIP IRRIGATION CONGRESS,
Second International Drip Irrigation Congress,
California University and United States Department of Agriculture, Agriculture Research Service.
Second International Drip Irrigation Congress, July 7-14, 1974, San Diego, California.
(See 74:03F-006)

74:08B-004

### LOW PRESSURE JET CLEANING OF PLASTIC DRAINS IN SANDY SOIL,

Ford, H.W.
Florida University, Lake Alfred, Agricultural Research and Education Center.
Transactions of the American Society of Agricultural Engineers, Vol. 17, No. 5, p 895-897, September-October, 1974. 3 fig, 1 tab, 6 ref.

Descriptors: *Jets, *Drainage practices, *Subsurface drains, Cleaning, Drains, Drainage systems, Sludge, Florida, Agriculture

This paper describes a low pressure jetting method for removing sludges from plastic drains and from the surrounding thin gravel envelope utilized in Florida sandy soils. There was no sand infiltration using gravel envelopes 0.75 to 1.50 in thick with corrugated plastic polyethyleve pipe employed in drain installations. A low pressure jet cleaning system can function in 4- to 5-in. plastic drains up to 550 ft. in length where ochre and FeS are the primary deposits to be removed. Cleaning of the gravel envelope can be accomplished presumably by the surging action of jetting pressure. Jetting should be performed at a slow entry rate and with a hydraulic head above the drain. In sandy areas where sludges are a problem, jetting should be performed within 2 weeks after initial drain flow.

74:08B-005

### NUMERICAL ANALYSIS OF PUMPING FROM CONFINED-UNCONFINED AQUIFERS,

Rushton, K.R. and Turner, A.
Birmingham University, England, Department of Civil Engineering.
Water Resources Bulletin, Vol. 10, No. 6, p 1255-1269, December, 1974. 8 fig, 1 tab, 8 ref.

Descriptors: *Pumping, Aquifers, Wells, Groundwater movement, Numerical analysis, Drawdown, Groundwater.

A numerical method is presented for the analysis of a pumped well in a homogeneous aquifer with allowance made for the decrease in saturated depth, vertical components of flow, the possibility of regions of the aquifer changing between the confined and unconfined states and the effect of different outer boundaries. The method is based on a discrete space, backward difference time, approximation. A particular example considered in detail concerns heavy pumping from one of a regular array of wells in an unconfined aquifer until the drawdown in the well reaches a critical value. Non-dimensional curves are presented relating the time and volume dewatered to the quantity discharged from the well. A further example investigates the effect of an initial confining pressure on the aquifer behaviour.

74:08B-006

### ECONOMIC PIPE SIZING FOR GRAVITY SPRINKLER SYSTEMS,

Perold, R.P.
Stellenbosch University, Republic of South Africa, Agricultural Engineering Department.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 100, No. IR2, p 107-116, June, 1974. 3 fig, 4 tab, 2 ref, 2 append.

Descriptors: *Pipelines, *Pipes, Economics, Sprinkler irrigation, Irrigation, Irrigation design, Irrigation engineering, Hydraulic design, Hydraulics.

A method is described for finding the most economical pipe sizes in gravity systems by comparing financial gains and losses resulting when pairs of changes in pipe size are made in various portions of a system in such a way that the additional pressure losses and gains balance. The influence of branches is treated and application to time-variable branched flow is examined. As shown in examples, the method rapidly gives the most economical solution.

## Section XXXI

## ENGINEERING WORKS

### HYDRAULIC MACHINERY (Group 08C)

74:08C-001
TRICKLE IRRIGATION IN MICHIGAN ORCHARDS: CONTROLLING RATE OF FLOW WITH FLOW REGULATING VALVES AND MICROTUBES,
Kenworthy, A.L. and Kesner, C.
Michigan State University, East Lansing, Michigan.
Proceedings of the Second International Drip Irrigation Congress, pp. 275-280, July 1974. 3 fig, 2 tab, 2 ref.

Descriptors: Flow rates, Michigan, Irrigation systems, Orchards, Irrigation, Agriculture.

An appropriate combination of flow regulating valves and microtubes of different inside diameter has been found ideal for studying rates of flow in trickle irrigation. The flow regulating valve is installed in a row lateral. Capacity of the valve is selected to provide the amount of water desired for the row. To distribute the water and counter elevation changes, microtubes of different inside diameters are used and thus avoid excessive microtube lengths. Selection of an appropriate microtube ID in accordance to flow rate will permit a uniform value to adjust microtube length according to elevation change. Data on uniformity of water distribution is presented.

74:08C-002
DESIGN CHARTS FOR DRIP IRRIGATION SYSTEMS,
Wu, I.P. and Gitlin, H.M.
Hawaii University, Honolulu, Hawaii.
Proceedings of the Second International Drip Irrigation Congress, pp. 305-310, July 1974. 3 fig, 4 ref.

Descriptors: *Irrigation design, *Design flow, *Design criteria, *Hydraulic design, Hydraulics, Irrigation systems, Irrigation, Agriculture, Design.

A simple design procedure has been developed for drip irrigation systems installed on either uniform or non-uniform slopes. The charts presented can be used to design a system with an allowable discharge (emitter) variation up to 20%. A dimensionless energy gradient curve has been developed theoretically for drip irrigation lines, submain and lateral, and was checked by laboratory and field experiments. It was found that a typical dimensionless energy gradient curve which was developed by using turbulent flow in smooth pipe can be used for flow conditions having 20% discharge (emitter) variation and percentage of laminar flow up to 30%. The dimensionless energy gradient curve combined with different slope conditions will show the pressure variation along the drip irrigation line. Design charts have been developed for both single tubing and twin-chamber drip irrigation systems. Examples are presented showing the design procedure.

74:08C-003
HIGH-PRESSURE WATER JET CLEANING OF SUBSURFACE DRAINS,
Grass, L.B. and Willardson, L.S.
United States Department of Agriculture, Agricultural Research Service, Brawley, California, Imperial Valley Conservation Research Center, Western Region.
Transactions of the American Society of Agricultural Engineers, Vol. 17, No. 5, p 886-888 and 891, September-October 1974. 7 fig, 8 ref.

Descriptors: *Jets, *Drainage practices, *Hydraulic equipment, *Hydraulic machinery, Cleaning, Tile drains, High pressure, Drains, Drainage systems, Hydraulics, Subsurface drains, Agriculture.

High pressure jetting equipment utilized the macerating action of high-velocity water jets and vigorous water turbulence to clean roots, silt, and chemical deposits from subsurface drains. Water exiting from the rear jets propels the nozzle and hose up the drain. Two types of nozzles are most commonly used in Imperial Valley: (a) the cleaning nozzle used mainly for removing silt and mineral deposits requiring a pump pressure of 1250 psi and a nozzle pressure of 700 psi; and (b) the penetrator nozzle, used mainly for removing root plugs and the larger, more difficult accumulations of silt requiring pump pressure of 1000 psi and a nozzle pressure of 500 psi. A dewatering pump is used to remove the dislodged material arriving at the tile opening. The jet cleaning operation also can locate breaks in subsurface drain lines so that they can be repaired.

## Section XXXII

## ENGINEERING WORKS

### SOIL MECHANICS (Group 08D)

74:08D-001
SEEPAGE RATES AND THE HORIZONTAL FLOW APPROXIMATION,
Youngs, E.G.
Agricultural Research Council, Cambridge, England, Unit of Soil Physics.
Water Resources Research, Vol. 10, No. 4, p 874-876, August 1974. 5 fig, 6 ref, 1 append.

Descriptors: *Seepage, *Dams, *Groundwater movement, *Porous media, Conductivity, Dupuit-Forchheimer theory, Hydraulics.

Attention was drawn to a particular case of seepage through a porous body in which the flow is everywhere horizontal and hence easily calculated. In an appendix the seepage through a dam core with a cross section in the shape of an isosceles triangle was shown to be estimated with sufficient accuracy for practical purposes by the horizontal flow approximation.

74:08D-002
POWDERED METAL PLATES FOR CONSTRUCTING UNSATURATED FLOW CELLS,
Bianchi, W.C.
United States Department of Agriculture, Agricultural Research Service, Fresno, California, Water Management Research.
Soil Science Society of America Proceedings, Vol. 38, NO. 4, p 683-684, July-August, 1974. 3 fig, 1 tab, 4 ref.
(See 74:02G-021)

74:08D-003
SMALL TENSIOMETERS FOR FIELD AND LABORATORY STUDIES,
Rogers, J.S.
United States Department of Agriculture, Agricultural Research Service, Gainesville, Florida.
Soil Science Society of America Proceedings, Vol. 38, No. 4, p 690-691, July-August, 1974. 1 fig.
(See 74:02G-022)

74:08D-004
DETERMINING EFFECTIVE SOIL WATER DIFFISIVITIES FROM ONE-STEP OUTFLOW EXPERIMENTS,
Gupta, S.C., Farrell, D.A., and Larson, W.E.
Minnesota University, St. Paul.
Soil Science Society of America Proceedings, Vol. 38, No. 5, p 710-716, September-October, 1974. 7 fig, 15 ref, append.
(See 74:02G-023)

74:08D-005
EFFECT OF BACKFILL ON DRAIN FLOW IN LAYERED SOILS,
Hwang, R.B., Luthin, J.N. and Taylor, G.S.
California University, Davis.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 100, No. IR3, p 267-276, September, 1974. 4 fig, 1 tab, 10 ref.

Descriptors: *Drainage practices, Drainage engineering, Drains, Soil profiles, Soil properties, Hydraulic conductivity, Backfill, Compaction, Compacted soils.

The purpose of the work presented herein is to shed some light on the transient flow towards drains in layered soils with the ultimate goal of improving the techniques of drainage design. The combination of layers occurring in the field soils is very great but experience shows that many soils can be treated as two-layered soils from a standpoint of drainage design. Trial-and-error methods in the field may well be the best way to treat some of the more complicated soil layering problems. However, for soils that can be approximated by a two-layer model the results presented herein will improve our understanding of the flow towards drains and the effect of the backfill material on such flow.

74:08D-006
EFFECTS OF WATER MANAGEMENT AND SOIL AGGREGATION ON THE GROWTH AND NUTRIENT UPTAKE OF RICE,
Obermueller, A.J. and Mikkelsen, D.S.
California University, Davis, Department of Agronomy and Range Science.
Agronomy Journal, Vol. 66, No. 5, p 627-632, September-October, 1974. 5 tab, 20 ref.
(See 74:03F-162)

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